ONE-TO-ONE TECHNOLOGY AND MATHEMATICS ACHIEVEMENT FOR EIGHTH GRADE GIRLS AND BOYS IN THE STATE OF MAINE

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This study analyzed the eighth grade mathematics portion of the spring 2004 Maine Educational Assessment (MEA) achievement test and the survey questions that were also administered. The analysis was on a school-wide level (n = 182). The two survey questions used were: “Which statement best describes the use of calculators in your mathematics classes?” and "Which statement best describes how you use your laptop in mathematics class: getting data from the Web, finding mathematics problems online, creating graphs?"

Correlational analysis, partial correlation, and regression were used to determine if there was any association between calculator usage, laptop usage, and mathematics achievement for girls and for boys in the first state-wide group of students to have one-to-one laptops in Maine. Calculator usage was found to be positively associated with mathematics achievement for both girls (partial correlation coefficient of .189 (p = .011)) and for boys (partial correlation coefficient of .193 (p = .010)) even after controlling for school size and socio-economic status. Though no significant association between laptop usage and mathematics achievement for either girls or boys was found, this may be more a reflection on the survey question being a weak measure than the usage of laptops. In a post-hoc analysis of findings, schools were rank ordered based on the average mathematics achievement score regardless of gender; the top 25% (n = 45) and the lower 25% (n = 45) of the schools were evaluated. In the top 25%, there was no statistically significant difference between school-wide girls' and boys’ mathematics achievement scores. However, in the lower 25% of the schools, there was a statistically significant difference (*p* = .01) between the school-wide average of girls' and boys’ mathematics achievement scores, with the girls’ score being 1.49 points higher (*p* = .01, *d* = .447) than the boys’. Recommendations for refinement of MEA survey questions as well as future studies are provided.

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Thank you also to the state officials, teachers, pre-service teachers, faculty members, and librarians in the state of Maine who answered emails and phone calls, were willing to be interviewed, and went out of their way to help make this as accurate and as thorough a study as possible.

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CHAPTER 1

INTRODUCTION

Description of Problem

Mathematics Education: A Longstanding National and International Concern

"History changed on October 4, 1957, when the Soviet Union successfully launched Sputnik I" (NASA, 2003, ¶1). As the Space Race began between the United States and the then Soviet Union, the nation pressed for better mathematics and science education in order to train future scientists who could lead the United States to victory in that race (Devitt, n.d.).

Nearly 50 years later, the United States is still concerned about mathematics education and mathematics achievement. On April 18, 2006, President George Bush created the National Mathematics Advisory Panel (US Department of Education, 2006). The panel's purpose is to advise the President and the Secretary of Education on the best use of scientifically based research on the teaching and learning of mathematics. "To gain an edge in the 21st century global economy, America's high school graduates need solid math skills, whether proceeding to college or going into the workforce. The rest of the world is 'gathering strength' and forcing us to catch up" (US Department of Education, 2006, section 4).

The Trends in International Mathematics and Science Study (TIMSS), started in 1994-1995, has studied mathematics and science achievement in over 50 countries at various grade levels. This ongoing study is one of several that compare and contrast mathematics achievement within and between nations, over time, and within a given year. Additionally, TIMSS analyzes the gender differences in the achievement of the students in those nations and analyzes curriculum, pedagogy, and educational policy in those countries (TIMSS & PIRLS International Study Center, 2005). The international concern as well as the national concern for understanding and improving mathematics achievement appears to be ongoing and growing.

Purpose of the Study

The current study addresses a multi-faceted question of technology's potential for strengthening the learning of mathematics for girls as well as for boys. One-to-one laptop usage, calculator usage, or combinations of the two are evaluated as to their ability to strengthen the learning of mathematics, specifically addressing gender differences, or lack thereof, as measured by standardized mathematics achievement tests. The primary question of interest for the current study is: Among schools with an eighth grade in the state of Maine, is there any association between girls' mathematics achievement, boys' mathematics achievement and the level of calculator, laptop, and/or combined technology usage?

Rationale

Gender Equity: An Ongoing Concern

Sheila Tobias (1978) was among the first to bring attention to the disparity in mathematics education between females and males, from junior high and high school through college and into adulthood, in her book, *Overcoming Math Anxiety* (Moskowitz, 1978). Discussions have ensued ever since, in academia, in corporate America, and even in the popular press, (Bombardieri, 2005, January 17; Deloitte & Touche, 2005; Ripley, 2005, March 7a) on the existence or non-existence of gender differences in mathematics abilities, mathematics capabilities, and mathematics achievement. The theories include biological, social, psychological, and environmental differences (Casey, Nuttall, & Pezaris, 2001; Eccles & Jacobs, 1986; Linn & Hyde, 1989; Rabinowicz et al., 2002; Reyes & Stanic, 1988).

In 2004, the state of Maine created the Task Force On Gender Equity In Education. This Task Force was formed "as a result of educator concerns regarding poor academic performance by boys in Maine." The Task Force's purpose is to "recommend policies and strategies to promote gender equitable education" ("Task force on gender equity in education", ¶ 1). In her executive summary of the 1998 American Association of University Women (AAUW) report, *Gender Gaps: Where Schools Still Fail Our Children*, Maggie Ford, then national president of AAUW said,

> Equity without excellence would be a terrible waste of talent. Excellence without equity is a contradiction in terms. . . . When equity is the goal, all gaps in performance warrant attention, regardless of whether they disadvantage boys or girls. . . . In a gender-equitable and rigorous school system, gender gaps would be insignificant and all students would excel" (American Association of University Women (AAUW), 1999, p. iv).

Concern for true gender equity is a national concern as well as one for the state of Maine.

Maine: A Unique Opportunity

As described in more detail in the History and Background of Maine Learning

Technology Initiative (MLTI) section of Chapter 3, in March 2000 Angus King, then governor of Maine, announced plans to equip all middle school students and teachers with a laptop computer ("MLTI 2000 timeline", n.d.). The first laptops were issued in 2002 to seventh graders who used them again in eighth grade. Each year since, seventh graders have been issued laptops for use in seventh and then again in eighth grade. In 2006, 4 years after the initial deployment, the state announced the project would continue for another 4 years (Mao, 2006, June 29). Not only is the state of Maine the first state in the United States to implement a one-to-one technology initiative statewide, it is becoming a systemic change.

The Maine Educational Assessment (MEA) is a validated, state-wide standardized test of academic achievement (Measured Progress, 2004). In addition to traditional standardized achievement questions, survey questions are asked that give insights into student perceptions of the use of technology in their mathematics class and their perceptions of the curricular process:

- Are they graded on a rubric?
- Does their classwork consist of journals and portfolios?
- Does the MEA reflect what they've been taught?

The MLTI provides a unique opportunity to look at a whole population—every eighth grader in the state—using standardized achievement tests as a measure, then correlate this test data with the survey data regarding student perceptions of how and what they were taught that year.

Technology: A Possible Educational Answer to Address These Concerns Technology in General

Can technology make a difference? As outlined in the following two sections, schools, districts, and states across the United States are assessing a variety of technologies including calculators, specific software, personal digital assistants, and laptops for use in the classroom. Reports in the field seem to conclude that more information is needed. For example, Dickey and Roblyer (1997) examined the impact of technology on educational effectiveness in the United States as measured by the National Assessment of Educational Progress (NAEP) and the TIMSS. They found five test items that may favor students with technology experience, but conclude that further research is needed to determine if technology can indeed have a positive effect on achievement.

Graphing Calculators

In the report *Handheld Graphing Technology in Secondary Mathematics: Research Findings and Implications for Classroom Practice* (Burrill et al., 2002), the editors describe their frustration with the lack of in-depth analysis of the impact of calculator usage on achievement in general and especially in sub-groups of the population such as gender, race, socio-economic status (SES), and ability level:

> Since the production of the *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989) that recommended the use of technology for all students, many researchers and educators have raised questions about equity issues arising from the cost of technology. Others expressed concern that the technology would only be available to students in certain ability groups. Some were concerned that female students would react negatively, while males would embrace the technology,

> leading to differential learning outcomes. In *The Nation's Report Card: Mathematics 2000* (National Center for Educational Statistics, 2000), an effort was made to describe students' access to calculators and examine the relationship between access in mathematics classes and student performance on the mathematics portion of the National Assessment of Educational Progress (NAEP)—which allows all students to use scientific calculators on certain items. According to this report, 62 percent of the twelfth grade students reported using graphing calculators in their mathematics courses, and there was a positive relationship between frequency of use and NAEP score (p. 165). These results raise the question, "Who are these students? How do their characteristics vary with regard to gender, race, socio-economic status, and ability level?" Unfortunately, this information was not available. This was a common result in our efforts to locate multivariate equity studies. (pp. 50-51)

One Laptop for Every Student and Teacher: A New Area of Inquiry

In her March 2004 report to Florida's Commissioner of Education, Barrios reviewed 10 Florida laptop projects and 25 laptop projects outside of Florida. Most of the findings related to "lessons learned" such as the importance of teacher professional development and that "the 'drill and kill' method just doesn't work for students anymore" (Barrios, 2004, p. 35). Of the 35 projects studied, only 1 project quantified increased achievement, the rest were anecdotal. (The 1 project with quantified achievement was Henrico County, Virginia discussed in fuller detail in Chapter 2, Review of the Literature.) Though research-oriented projects and laptop projects with stronger evaluation components are starting across the country, longitudinal studies in this new field are not yet available.

The Mid-Atlantic Regional Technology in Education Consortium (MAR*TEC) included a chapter in their *Technology Coordinator's Notebook* titled "Laptop Initiatives: How Are They Working?" (Hendricks, 2004). Hendricks writes that more than 1 million students and teachers in the United States are using laptop computers, but only a few educational communities have conducted scientifically-based research projects that included academic achievement using statistical methods to control for independent variables such as ethnicity, gender, economic status, and prior knowledge. The conclusions of this overview were that

> . . . teachers, students, administrators, and parents perceive that one-to-one computing access is beneficial to education. However, perceptions are not a solid basis for spending millions of dollars on technology equipment. Three evaluation studies matched laptop students with similar nonlaptop peers; the research showed a positive correlation between participation in laptop programs and increased academic achievement. Since students and some teachers volunteered for these programs, there is no scientific way to determine if the laptop, teachers, or participation in a new program accounted for the added value. (last section, final ¶)

Conceptual Framework

Gender Differentiation in Mathematics Education

Several researchers suggest that girls tend to need meaningful and relevant learning scenarios (Boaler, 1998; Jackson, 1995; Sax, 2005) for mathematics education to be effective. Jackson's findings suggest that it may be:

> . . . less the case that females have no interest in numbers than that numbers have not been made interesting to females. Without a context that is meaningful to the girl, mathematics is pointless and mathematics achievement is low. Changing the context in which numerical information is presented and tested may enhance females' interest, attention and, ultimately, math performance. (p. 568)

Boaler, based on her research in the United Kingdom, claims that using a model of mathematics teaching that is open and project-based "may be able to eradicate underachievement and disaffection amongst girls" (Boaler, 1997, p. 285). Boys tend to do well in meaningful and relevant learning scenarios as well, but they also do well (or at least, better than girls) in traditional learning scenarios that are textbook-based, often presenting numbers in isolation and not in a context (Boaler, 1998, p. 41). Sax reports that to get girls "excited about 'pure' math and geometry, you need to connect it with the real world" (Sax, 2005).

Seymour Papert, "internationally recognized as the seminal thinker about ways in which computers can change learning" (Mao, 2006, June 29), was a key leader in the initial planning of MLTI. About the project, he said, "The idea for this is to be fun not in spite of being hard, but because it is hard. Kids don't mind hard, they mind boring" (Muir & Manchester, 2003, p. 1).

Project-Based and Place-Based Learning

The focus of MLTI was on learning, not technology (King, 2006). In fact, it is now generally referred to as "Maine Learns" re-emphasizing that MLTI is no longer just an initiative and has a focus on “making learning more dynamic, engaging, and personalized” (C. Lemke & Martin, 2003, p. 5). A large support network was put into place to help teachers both before and during the school year, to use the laptops in project-based situations (giving students opportunities to apply and synthesize knowledge) and place-based learning situations (learning connected to the community) (Muir & Manchester, 2003). Both project-based and place-based learning situations provide a meaningful context for numbers that should enhance the "interest, attention, and ultimately, math performance" of the girls as well as the boys.

Transfer of Learning

Haskell (2001) defines transfer of learning as "how previous learning influences current and future learning, and how past or current learning is applied or adapted to similar or novel situations. Transfer, then, is not so much an instructional and learning technique as a way of thinking, perceiving, and processing information" (p. 23). In his taxonomy of the transfer of learning, Haskell describes six levels of transfer: nonspecific transfer, application transfer, context transfer, near transfer, far transfer, and displacement or creative transfer. Near transfer occurs when "previous knowledge is transferred to new situations that are closely similar but not identical to previous situations" (p. 29). Taking a concept that one has learned in a mathematics class and applying it to a question on the same concept on a multiple-choice or short answer achievement test question would, in most cases, be considered near transfer. In describing the importance of his theory of learning transfer, Haskell states:

> . . . in slow-changing traditional societies, there's much less need for transfer of learning. The demands of our modern civilization, however, make transfer increasingly important. In our highly complex, rapidly changing, Information Age, the ability to transfer or generalize from the familiar to the less familiar, from the old to the new, not only renders our world predictable and understandable, but is a necessity for our adaptation to the technological and global demands of the 21st century. (p. 37)

When Angus King proposed the MLTI laptop initiative, he recognized that "jobs and the economy were changing and that both the ability to use technology and the ability to learn would be key to Maine's being competitive" (Muir, Knezek, & Christensen, 2004, p. 6). The hope of Governor King to create a program that would help the children of Maine learn how to learn and be competitive in the 21st century is a match for the promise of Haskell's transfer of learning theory. Based on Haskell's theory, one could conjecture that when 21st century tools (laptops) are used well in a one-to-one educational environment that learning and transfer of learning can happen. These conjectures will be presented as research questions and testable hypotheses in the Methodology chapter.

Definition of Terms, Limitations, and Delimitations

Definitions of Terms

One-to-one Computing

There is not yet a single, generally-accepted term for the new phenomena of having computers for every student. Ubiquitous is defined by Merriam-Webster (Merriam-Webster, 2006) as "existing or being everywhere at the same time: constantly encountered". The term "ubiquitous computing" is so new that it is not in traditional dictionaries but it has emerged as a description of having computers everywhere (freedictionary.com, 2006). In education it is not specific as to whether there is one computer assigned to each person or there are enough computers so that everyone has access to a computer anytime he or she wants. For the purposes of the current study, the term "one-to-one computing" will be used to describe the situation in Maine where every seventh and eighth grader is issued a laptop and has exclusive access to and use of that laptop computer for the entire school year.

Level of Calculator Usage

In the state achievement test for eighth graders in the state of Maine, survey questions are administered along with the achievement questions. One of the survey questions asks, "Which statement best describes the use of calculators in your mathematics classes?" (Measured Progress, 2004, p. 219). The choices are: A. Calculators are used daily. B. Calculators are used once or twice a week. C. Calculators are used once or twice a month. D. Calculators are rarely or never used. These choices represent a continuum delineating how often calculators are used in the mathematics classroom, ranging from not at all to daily. This quantity will be referred to in this study as the level of calculator usage.

Variety of Laptop Usage

A survey question asked on the eighth grade state achievement test regarding laptop usage was, "Which statement best describes how you use your laptop in mathematics class: getting data from the Web, finding mathematics problems online, creating graphs?" (Measured Progress, 2004, p. 219) The choices are: A. We do one of these. B. We do two of these. C. We do three of these. D. We do none of these. These choices do not reflect an amount of time, but rather the different ways in which the laptop is used. Therefore "level of laptop usage" does not describe what is being measured. Instead, this quantity will be referred to as the variety of laptop usage.

Limitations

The source data used in this study is aggregate data from schools reported as an average score without standard deviation. The unit of study is not a class of students with the same teacher, nor is it individual students. The unit of study is the school level.

There is no formal treatment comparison group because all students in the State had access to the intervention. The current study is an analysis of the entire population without a comparison group.

It is not known which schools had teachers who implemented project-based and problem-based learning or to what extent those teachers implemented the curricular approach that was offered in the professional development workshops.

"Researchers recognize that broad, large-scale initiatives often take several years before there are discernable changes to achievement" (Muir, Knezek, & Christensen, 2004, p. 9). The data used in the current study are from the second full year of MLTI; however, one can conservatively describe this study of achievement as the first year of the eighth grade implementation of one-to-one computing. Though the students had the laptops for one school year before entering eighth grade (when they were in the seventh grade), it was the first year for the eighth grade teachers to have laptops for their professional use or to have the opportunity for professional development in how to teach using laptops.

The current study relies on self-report data, which may not provide a completely accurate measure of the variety of laptop usage, the level of calculator usage, or even the course enrollment of the students. Students may intentionally or unintentionally provide incorrect information, or they could possibly misunderstand either the question or the choices given. Surveys are often subject to bias, since students

> . . . know they are being studied, and have at least some idea why [they are being studied], they may change their answers, either consciously or unconsciously, to show themselves in a better light or to conform to the expectations of those who are studying them (Doyle, 2004, inherent limitation no. 3).

Another limitation is the question of the ability of achievement tests to demonstrate learning. No Child Left Behind legislation, a reform of federal education policy, has mandated that standardized tests be aligned with standards (Office of the White House Press Secretary, 2002). Though its purpose is to insure that what is being taught aligns with what is being tested, there is no guarantee that students actually demonstrate their learning on those tests. One concern is the "high stakes" associated with the test. What has become known as "Campbell's Law" states that, "The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor" (Campbell, 1996, Corrupting Effect of Quantitative Indicators, ¶ 1).

Current course enrollment is known to have an effect on mathematics achievement test scores. Muthén and Burstein (1991) demonstrated that some test items have a much higher rate of being answered correctly depending on a student's "opportunity-to-learn." If a question is based on a definition that a student may not have been exposed to in class, there is much less chance of that student getting the answer correct than on a question where a student might be able to mathematically figure out the answer even if he or she had not been exposed to that mathematics concept in class. Reyes and Stanic state that differences in mathematics achievement cannot be fully explained if the factors of race, gender, and SES are studied in isolation from each other (Reyes & Stanic, 1988). Though the current study will look at gender and SES, there is little racial diversity in this population—Maine's population is 98%

Caucasian (Maine State Planning Office, n.d.)—so the findings of this study will address gender and SES but not race, and will therefore not be generalizable to an ethnically diverse population.

Limitations of the Data Source

It would be preferable to know the extent or level of laptop usage in each of the three categories: getting data from the Web, finding mathematics problems online, and creating graphs. For example, a question on the extent of laptop usage for the category of finding mathematics problems on the Web could be, "Which statement best describes the use of laptops for the purpose of finding mathematics problems on the Web in your mathematics classes? A. Laptops are used daily for finding math problems on the Web. B. Laptops are used once or twice a week for finding math problems on the Web. C. Laptops are used once or twice a month for finding math problems on the Web. D. Laptops are rarely or never used for finding math problems on the Web." However, that was not asked in the survey and therefore, the current study is limited to the data at hand that only asks students about the variety of laptop usage in their class.

Calvert and Engelhard (2000) cite Tate (1997) and Willingham and Cole (1997) when they warn that the nature of gender differences can be masked when comparing mean scores. They had access to individual item responses on the Second International Mathematics and Science Study and were able to analyze gender differences in specific sub-categories of mathematics achievement question types. Such data were not available from the state of Maine.

Only 215 of the School Profile reports of the 231 schools with an eighth grade were available for this study. In addition, schools that did not report either an average girls' mathematics achievement score or an average boys' mathematics achievement score (or both) were eliminated from the overall dataset, leaving 182 schools that were included. Of the 182 schools that were included, 2 did not report a percentage of students that were not economically disadvantaged, thus in analyses that involved SES, the data from only 180 schools were used.

Delimitations

The current study is restricted to only calculators and laptops. Though students were asked survey questions about the use of rubrics, journals, group work, and other curricular approaches and assessment techniques utilized in their mathematics classroom, these answers were not used in the analysis. The current study is restricted to the association of level of calculator usage and variety of laptop usage to the school-wide average mathematics achievement for female and male sub-populations.

It is unknown if calculators are equally available to all students and teachers in the state of Maine. However, for the purposes of the current study, it is assumed that calculators are available to all students in adequate numbers. This assumption is based on generalizing national data to Maine. In the 2000 National Survey of Science and Mathematics Education: Status of High School Mathematics Teaching, 78% of teachers reported using graphing calculators and 2% reported that they felt such usage was needed but they did not have access. However, 20% reported that they did not feel the use of graphing calculators was needed, so it is not known if these classes had access to calculators and chose not to use them or did not have access to calculators (Whittington, 2002a). Similar findings were reported in the middle school version of this report concerning four-function calculators, with fewer teachers using graphing calculators in middle school and more teachers responding that they did not think graphing calculators were needed in middle school (Whittington, 2002b). Generalizing these national findings to Maine, one would expect that at least 80% of Maine's seventh and eighth grade classrooms have access to calculators, and potentially, some percentage of additional classrooms may have access to calculators but choose not to use them.

CHAPTER 2

REVIEW OF THE LITERATURE

Mathematics Education: A Longstanding National and International Concern

The United States Compared to the Rest of the World

A variety of assessments have been administered to children all over the world for the purpose of assessing educational success across national policies, pedagogies, and educational practices. The United States tends to rank fairly low among participating countries in the areas of middle and high school mathematics.

In 1994-95, The International Mathematics and Science Study (TIMSS) was conducted at five grade levels in more than 40 countries. More than half a million students were tested in mathematics and science. Similar studies were conducted in 1999 and 2003. The project (first called The International Mathematics and Science Study, now called Trends in International Mathematics and Science Study) has narrowed its focus to fourth and eighth graders as well as the final year of schooling. The surveys and achievement tests are administered every four years; TIMSS now includes over 50 countries (TIMSS & PIRLS International Study Center, 2005). These studies compare and contrast mathematics achievement within a participating nation as well as between nations, and often look at the gender differences in the achievement of those nations, in addition to analyzing curriculum, pedagogy, and educational policy in those countries. In the most recent study, "Lithuania, and the United States, as well as the benchmarking Canadian province of Ontario, showed a pattern of improvement from assessment to assessment with significant change over the 8-year period from

1995 to 2003" (Mullis, Martin, Gonzalez, & Chrostowski, 2004, p. 4). In the 1995 study, the United States was 18th in the mathematics average scale score out of the 25 countries that met sampling criteria (Beaton et al., 1996). In 2003, the average score of eighth-graders in the United States placed them 10th out of 44 participating countries (Gonzales et al., 2004).

The Program for International Student Assessment (PISA) is another system of international assessments that measures 15-year-olds' capabilities in reading literacy, mathematics literacy, and science literacy every three years. PISA was first implemented in 2000 and is carried out by the Organization for Economic Cooperation and Development (OECD), an intergovernmental organization of industrialized countries (M. Lemke, 2004). According to the National Council of Teachers of Mathematics (NCTM), the mathematics skills of U.S. 15-year-olds received lower scores, on average, than those of students in other participating countries in the 2003 PISA. In the United States, 5,456 students in 262 schools were assessed; more than 250,000 students were assessed worldwide. Fifteen-year olds in the United States placed 24th out of 29 countries. In problem solving, students in 25 countries performed better than their United States counterpart (National Council of Teachers of Mathematics, 2005).

In 2003, US performance in mathematics literacy and problem solving on the PISA was lower than the average performance for most OECD countries. The United States also performed lower than the OECD average on each mathematics literacy subscale for specific content areas: space and shape, change and relationships, quantity, and uncertainty (M. Lemke, 2004).

The United States tends to compete well on an international level in mathematics achievement in the fourth grade but rankings drop by eighth grade, as reported by researchers from Penn State in their analysis of TIMSS data (Science Daily, 1998, ¶ 7). They reported that this drop was not "a slump (as many educators and members of the press have called it)" but is due to "a continuation of low gains from year to year" (Science Daily, 1998¶ 7). It is not high performance in other countries that pushes the scores of the United States down, "but something the U.S. is doing, or not doing in its education systems that creates this mediocrity" (Science Daily, 1998, ¶ 7).

Maine Compared to the Rest of the United States

In October 2005, the commissioner of Maine's Department of Education announced that Maine had outscored the United States' national average on the National Assessment of Academic Progress (NAEP), often referred to as "the Nation's Report Card." Maine's average score was 281, while the country's average was 278 (Gendron, 2005). As shown in Figure 1, based on data from the NAEP Data Explorer online database (National Assessment of Educational Progress, 2006), Maine's average score on the NAEP has remained consistently high with little variance between boys' and girls' achievement. Except for the first year, 1992, when the scores were tied at 279, the boys scored higher than the girls but not by enough points to be educationally meaningful. Looking at the effect-size of the difference between Maine boys' and girls' mathematics achievement on the NAEP (see Table 1), the largest effect-size (Cohen's d) is .065 which is close to zero (0) on a scale of zero to one and not even reaching the range that would be considered small according to the guidelines provided by Cohen (1988) of .2 = small, .5 = moderate, and .8 = large.

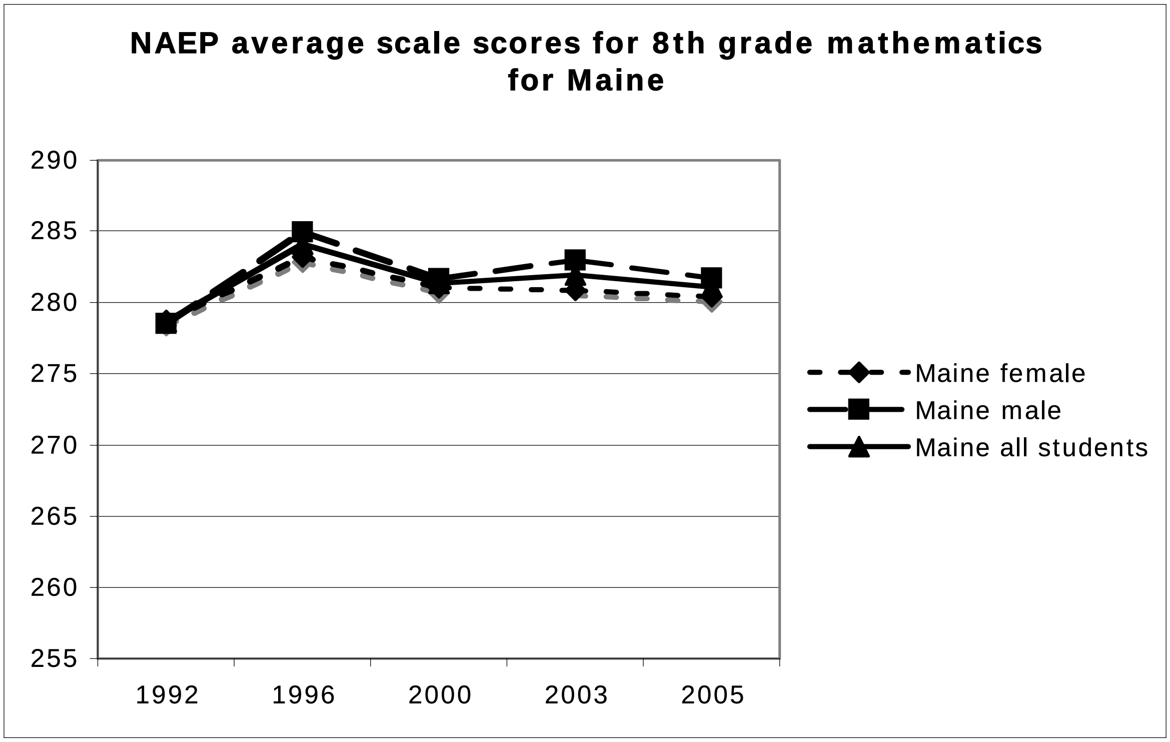

Figure 1. NAEP average scale scores for eighth grade mathematics for Maine.

Table 1

NAEP Scores in Eighth Grade Mathematics for Maine Boys and Girls

Year	Boys' math score	*SD*	Girls' math score	*SD*	Cohen's *d*
1992	279	32	279	29	<.005
1996	285	32	283	30	0.064
2000	282	35	281	32	0.030
2003	283	31	281	31	0.065
2005	282	34	280	32	0.060

Figure 2 illustrates what Gendron was referring to when later in the same report she said, “But the Nation as a whole has shown more dramatic improvement since 2000 and appears to be catching up with Maine" (Gendron, 2005, p. 3). Though the national average was lower than Maine's in 2005 and has been lower than Maine's score throughout NAEP history, the national average has been steadily climbing while Maine's average has been essentially constant across the 13-year period. As shown in Figure 2, based on data from the NAEP Data Explorer online database (National Assessment of Educational Progress, 2006), if the change rate for mathematics achievement stays the same for both the state of Maine and the nation, the national average mathematics achievement score will soon surpass that of the state of Maine. For Maine, "keeping up" the status quo of their mathematics achievement scores is not enough.

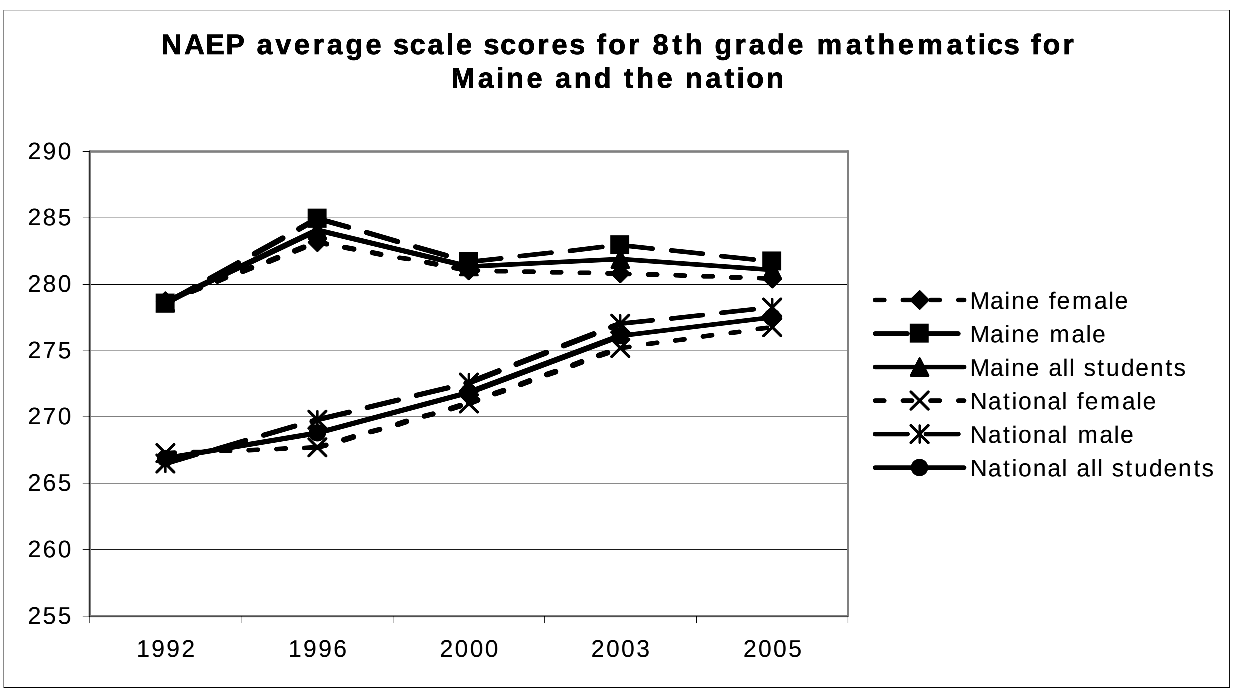

Figure 2. NAEP average scale scores for eighth grade mathematics for Maine and the USA.

Gender Differences in Mathematics Achievement

In an analysis of data gathered in the TIMSS for Spain and the United States, no mean gender differences were found on the total scores between genders in the United States. However, a micro-level analysis of item characteristics was considered when interpreting those results, and though within categories, the gender differences varied in size and direction depending on other characteristics of the item, it was also concluded that item difficulty was related to gender differences in both countries (Calvert & Engelhard, 2000). Another analysis of the same TIMSS data found that in eighth grade mathematics across all nations, few significant differences in mean achievement by gender existed. "Differences that did exist, however, tended to favor males" (Fierros, 1999, p. 1). In the 2003 TIMSS,

> At the eighth grade, girls had the advantage in more countries in the knowing domain of mathematics and, even more so in the reasoning domain. Internationally across the TIMSS 2003 participants, girls had significantly higher achievement, on average, than boys in both these domains. Boys had the advantage in more countries in the applying domain (Mullis, Martin, & Foy, 2005, p. 41).

In an analysis of open-ended items and multiple-choice items on the 1988 International Assessment of Educational Progress (IAEP) mathematics test, gender effects across six countries, where boys generally outperformed girls, were larger on multiple-choice items than on open-ended items. However in the 1991 IAEP, gender effects, again where boys generally outperformed girls, across 20 countries tended to be larger for open-ended items than for multiple-choice items. Beller and Gafni (2000) investigated the data further and found that it was not the item format but rather the item difficulty that accounted for gender differences. The correlations from both 1988 and 1991 suggested that the more difficult the items, the better that boys perform relative to girls.

Addressing Gender Equity

Gender Equity in General

Researchers have long noted that there are often gender differences in achievement, academic interests, and career choices. Theorists then proposed possible reasons why this occurs. As described in the following paragraphs, these theories include environmental—the way the children are raised and the toys they play with, social—the expectations that are set for children by adults, psychological, and biological. These theories typically hypothesize the differences in the way girls and boys learn and then conjecture the teaching strategy that will have the most positive impact on learning for each gender. Recently, there is even a theory that no real differences exist, only similarities. At this point in time, there is no definitive explanation as to the differences (if any) between girls and boys and their success in different subject matter areas.

In the biological realm, a group of medical researchers in Switzerland have studied slices of the cerebral cortex and compared the volume of individual nerve cells and the number of connections made by those cells in specific areas of the brain. Their findings show that there are fundamental gender differences in the structure of the human cerebral cortex. Males have higher neuronal densities, while females showed significantly larger neuropil volumes than males (Rabinowicz et al., 2002).

In addition to these varied and sometimes conflicting theories of why there are gender differences, there is also a researcher who hypothesizes that gender differences do not exist. Hyde (2005) proposes that there are more gender similarities than there are gender differences. Her review of over 46 meta-analyses from all over the world covers all ages from infant to elderly. She categorized the meta-analyses into six categories, those that assess cognitive variables, verbal or nonverbal communication, social or personality variables, psychological well-being, motor behaviors and miscellaneous constructs. Based on her meta-analysis, she claims that gender differences vary substantially in magnitude at different ages and that there are no significant differences between boys and girls.

Though not theory-related, concern for and interest in gender issues are actively discussed outside the research environment as well. In the corporate world, Deloitte & Touche, an American member of Deloitte Touche Tohmatsu, is an audit, tax, consulting, and financial advisory services company. In 1991, only 4 of its 50 partner candidates were women. In 1992, the Chairman and CEO of the company established the Task Force for the Retention and Advancement of Women (Deloitte & Touche, 2005). The purpose of the task force is to attract and keep "females in the pipeline for careers that require mathematical and technical skills" (2005, November 22, p. ¶ 2).

In the academic world, "The president of Harvard University, Lawrence H. Summers, sparked an uproar at an academic conference . . . when he said that innate differences between men and women might be one reason fewer women succeed in science and math careers" (Bombardieri, 2005, January 17, p. ¶ 1). The national discussion that followed was capped by *Time* magazine devoting an entire issue and the front cover to the controversy.

Gender Equity in Mathematics Education

Jackson (1995) observed 162 undergraduates and their ability to retain number information presented in male-related topics, female-related topics, and gender-neutral-related topics. Her findings suggest that it may be "less the case that females have no interest in numbers than that numbers have not been made interesting to females. Changing the context in which numerical information is presented and tested may enhance females' interest, attention and, ultimately, math performance" (p. 568).

Boaler carried out interviews with underachieving girls and found that girls link their underachievement, not to themselves, but to the type of mathematics that is widely taught in the UK, which they believe denies them access to understanding (Boaler, 1997). She also carried out three-year case studies of two schools with alternative mathematical teaching approaches. One school used a traditional, textbook approach; the other used open-ended activities at all times. Using various forms of case study data, including observations, questionnaires, interviews, and quantitative assessments, she showed that the two approaches encouraged different forms of knowledge. Students who

> . . . followed a traditional approach developed a procedural knowledge that was of limited use to them in unfamiliar situations. Students who learned mathematics in an open, project-based environment developed a conceptual understanding that provided them with advantages in a range of assessments and situations" (Boaler, 1998, p. 41).

Her conclusions were that both boys and girls, but especially the girls, benefited from the open, project-based environment.

Technology Usage and Its Impact on Academic Achievement

In 2006, the OECD released what they call the first internationally-comparative data on the opportunities 15-year-old students have for using computers at home and at school, how they use computers, their attitudes towards computers, and the relationship between computer use and performance in key school subjects. These findings were based on the PISA data from 2003. In general, 15-year-old boys report higher confidence than girls do in performing computing tasks and "these differences are particularly apparent for the more demanding computing tasks . . ." (Schleicher, 2006, slide 20). Students who are established computer users perform better on achievement tests than students with limited computing experience, but the performance advantage varies across countries and the difference diminishes somewhat when socio-economic background factors are taken into account. However, experience does not equate to frequent use. It appears that students who use computers in moderation perform better than students who are either not using computers (or using them rarely) or are using computers very often (Schleicher, 2006).

According to *Technology in American Schools: Seven Dimensions for Gauging Progress* (C. Lemke & Coughlin, 1998), while further research studies are needed, emerging trends indicate that under the right conditions technology:

- Accelerates, enriches and deepens basic skills

- Motivates and engages students in learning
- Helps relate academics to the practices of today's work force
- Increases economic viability of tomorrow's workers
- Strengthens teaching
- Contributes to change in schools
- Connects schools to the world (p. 3)

It is expected that the current study will affirm or reaffirm the first outcome of technology usage in eighth grade classrooms by looking at any association between mathematics achievement and the use of calculators and laptops. Lemke and Coughlin's fourth point of increasing economic viability of tomorrow's workers is consistent with Governor King's objective for one of the purposes of the Maine Learning Technology Initiative (MLTI).

Graphing Calculators

The National Research Council found that "instruction that makes productive use of computer and calculator technology has beneficial effects on understanding and learning algebraic representation . . . " (Kilpatrick, Swafford, & Findell, 2001, p. 420). A study of 16-year olds in Great Britain found that, "On the symbolization items, use of graphic calculators was associated not only with markedly superior attainment by all students, but with greatly enhanced relative attainment on the part of female students" (Ruthven, 1992, p. 431). Furthermore, on these items "female students in the treatment group outperformed the males, while in the control group the males outperformed the females" (Burrill et al., 2002, pp. 49-50).

One-to-one Laptops

The number of laptop programs is increasing in the United States; however, the research on the effectiveness of these programs tends to be mostly anecdotal at this time. In a report of the benefits of laptops by Apple Computer Company, their overview of several reports found that positive effects from studies of one-to-one laptop programs include increased technology use, increased technology literacy, and improved writing. There was no mention of increased mathematics achievement (Apple Computer Co., Inc. 2005).

The anecdotal evidence of these programs shows that laptops primarily provide students with opportunities to develop what have been dubbed as "21st century skills," such as problem solving, team work, and information processing. Quantitative evidence of the impact of laptop programs on state achievement tests is just emerging. After two years of implementation in a laptop program in Henrico County, Virginia, high school score results increased on all 11 of the Virginia Standards of Learning tests. In 2000, only 60% of Henrico County's regular schools were accredited according to Virginia Standards of Learning criteria. By 2003, 100% of Henrico County's regular schools were accredited. This includes 40 elementary schools, 11 middle schools, and 9 high schools (Barrios, 2004).

According to a National Science Foundation report (Zucker & McGhee, 2005), the Henrico County laptop project started in 2001 and reached its target by 2003 of one laptop for every middle and high school student and teacher. In 2001, high school teachers received laptops in the summer only a short period of time before school started and high school students received laptops at the opening of school. Many lessons were learned at the high school level; middle school teachers received laptops in December 2001 or January 2002 and middle school students did not receive laptops until January 2003, giving the teachers a full year to prepare for the technology in their curriculum. The report summarizes,

> By giving laptop computers to more than 25,000 teachers and students in grades 6 to 12, Henrico County Public Schools (HCPS) in Virginia became the largest school district in the United States to implement one-to-one computing in its middle and high schools. HCPS established wireless local area networks in all of its schools, invested in new hardware and software, and provided a range of technology professional development to support the use of the laptops in daily instruction. (p. iii)

Dunleavy and Heinecke (in press) studied the effect of one-to-one laptop use on math and science achievement in at-risk middle school students. Using a pre-test post-test control-group design, the researchers compared the test scores of students randomly assigned to one-to-one laptop classrooms with the test scores of students in classrooms without one-to-one laptops in the same middle school. Students who had computers in seventh grade, and again in eighth grade, were the unit of analysis. Preexisting achievement scores for each student were used as the pre-test and were also used as a covariate to show that the groups were statistically equivalent. Results showed significant gains for science achievement, but no significant program gains for mathematics achievement. Furthermore, there was a gender effect in science achievement with boys significantly outperforming girls. However, no gender differences in mathematics achievement were noted in the same one-to-one laptop classroom. The results suggest that one-to-one laptop instruction can increase student achievement under certain conditions.

The Fullerton School District in Orange County, California launched a one-to-one laptop-learning program at three schools in the 2004-2005 school year. They claim that

> . . . in spite of the logistical challenges of the first-year implementation, the program has had important successes, especially in promoting the kind of learning skills required for the 21st century. The program is highly popular with participating teachers, students, and parents, who in their strong majority believe that it contributes positively to student learning (Warschauer & Grimes, 2005, p. 2).

In the first year of the program, they found that students in the laptop program, in general, improved in test scores from the prior year at about the same rate as other students in the district.

Technology and Gender Differences

Gender and Computer Attitudes

Christensen, Knezek, and Overall (2005) looked at trends across 1st through 12th graders in the area of computer enjoyment. They reported that boys and girls begin 1st grade with few or no differences in attitudes toward computers (Collis, Knezek, Lai, Miyashita, Pelgrum, Plomp, & Sakamoto, 1996). However, in their own study of data gathered from 10,000 Texas public school students in 3rd through 12th grades, by 4th and 5th grade, girls are more positive in their self-reported perception of computers. Starting about 6th grade, girls begin to become less positive in their enjoyment of computers than boys, and by eighth grade the girls' attitude becomes significantly lower than boys. The study suggested that attitudes may become similar again by the end of secondary school.

Lack of Gender Studies in Calculator Usage

As stated earlier, in *Handheld Graphing Technology in Secondary Mathematics: Research Findings and Implications for Classroom Practice*, the editors examined more than 180 published reports about calculators. They found 43 studies that met their criteria for inclusion in the report. Yet they describe their frustration in the lack of in-depth analysis of the impact of calculator usage on achievement in general and especially in sub-groups of the population such as gender, race, socio-economic status (SES), and ability level (Burrill et al., 2002).

Lack of Gender Studies in MLTI

In the MLTI research to date, little research has been done in the specific area of gender differences within the laptop initiative. At the Web site for the Center for Education Policy, Applied Research, & Evaluation at the University of Southern Maine (CEPARE), the main evaluation group for the MLTI, there are five summary reports on first phase of the initiative and four mid-year evaluation reports. These reports date from April 2003 through July 2004, the first year of the project.

The first report is titled *The Impact of Maine's One-to-One Laptop Program on Middle School Teachers and Students* and is 59 pages long (Silvernail & Lane, 2004). The word gender does not appear anywhere in this document and there are no references to gender differences associated with the initiative. The second report is titled *Laptop Use By Seventh Grade Students with Disabilities: Perceptions of Special Education Teachers* and is 16 pages long. The word gender, or any reference to gender differences, also does not appear in this report (Harris & Smith, 2004). The fourth report, *Use of Laptop Computers and Classroom Assessment: Are Teachers Making the Connections* contains 21 pages and no occurrence of the word gender (Beaudry, 2004). The fifth report *Two Teachers Implement One-to-One Computing: A Case Study* has 8 pages and the word gender is not used in the report (Garthwait & Weller, 2004).

In the mid-year evaluations by the CEPARE, there are four reports. One 23-page report, *Occasional Paper #3* (Sargent, 2003), has no occurrence of the word gender. One 66-page report, *Mid-year Evaluation Report* (Silvernail & Harris, 2003), and one 31-page report, *Occasional Paper #1* (Lane, 2003), each have only one occurrence of the word gender. That occurrence is in the Appendix where a sample of the student survey is displayed showing that the students are asked for their school name, their grade level, and their gender. The fourth mid-year evaluation report, *Early Evidence from the Field: The Maine Learning Technology Initiative: Impact on the Digital Divide* is a 21-page report. On page 6 of the report is the only occurrence of the word gender anywhere in this report on the digital divide. It is a definition of the term "digital divide" as provided by the Office for Information Technology Policy, "disparities/differences based on economic status, gender, race, physical abilities, and geographic location " (Gravelle, 2003, p. 5). Though the definition of digital divide includes gender as one of the differences to be addressed, it is in fact not addressed in the report.

Of the nine reports on the MLTI, the only one with any true reference to gender is Research Report #3 in the Phase One Summary Evidence Reports. This 36-page report titled, *Trading Roles: Teachers and Students Learn with Technology* (Fairman, 2004), has the word gender in it a total of three times. The first is a disclaimer, "Interview data described here are primarily from teacher and student interviews. Proper names used in quotations are pseudonyms, and gender is sometimes changed to maintain confidentiality" (Fairman, 2004, p. 6). The second occurrence is in the following quote:

> [I]f one kid's laptop isn't working, another child will always say, "Hey come on over and see what I've got," and it's not a boy/girl thing so much. I think that gender element in middle school isn't present there (teacher, pilot school, December 2002). (Fairman, 2004, p. 20)

The third occurrence of the word gender is in an opinion offered in the section called Benefits for Classrooms and School Communities,

> Teachers saw evidence that the laptops helped students to 'build bridges' across the barriers of academic ability, disability, gender, social grouping, and grade level. Hopefully, attitudes of respect, equity, and increased interaction across different groups of students have carried over into wider school activities and the school community. (Fairman, 2004, p. 24)

However, the report offers no substantiation of that opinion. Thus, the current study is among the first to quantitatively analyze gender as a factor in the MLTI.

School Size and Its Impact on Achievement

The Gates Foundation has been reported as funding over 1.4 billion dollars in education grants, mostly to promote smaller schools (Shaw, 2006, November 5). David Silvernail (2006), Director of the Maine Education Policy Research Institute (MEPRI), studied 14 reports on the importance and the impact of school size in student success. He points out that most of these findings are not applicable to Maine. The definition of "small schools" varied in the different reports but was always less than 1,000 students or often times less than 750 students. Of Maine's 115 high schools in 2005, only 29 had 800 or more students. Only 3 high schools are in the 1,200 – 1,400 student population category. Most "large schools" in these reports had over 2,000 students and there are no schools of that size in Maine. Some of the reports referenced in the Maine study analyzed only small urban city schools whereas Maine's small schools are almost exclusively rural.

In the report to the Joint Standing Committee on Education and Cultural Affairs of the Maine State Legislature, Silvernail (2006) gave a preliminary analysis of the cost and characteristics of Maine's higher performing schools. The legislature had made some exceptions to the state's class size rules and to the standardized funding formulas for a few high schools that were under 200 students, a few elementary schools that had less than 15 students per grade level, and the island schools that had considerably higher transportation costs. In an effort to be accountable for their expenditures, the legislature asked MEPRI to study the cost-effectiveness of these schools, and of Maine's high-performing schools in general. The analysis that compared the effectiveness of small schools to other schools in the state was inconclusive. Silvernail also looked at the costs required for a student to graduate (which is a different cost than annual expenditures per student), high attendance rates, low tardiness incidences, low bullying incidences, strong parental support, and other variables that are often touted as advantages of small schools. But the analysis in Maine did not show small schools to have the advantage in all of these areas. Using 3-year average scores on the state's standardized achievement tests and a "value-added" definition of higher performance, he found that "higher-performing" schools as well as "lower-performing schools" came in all sizes. This report does not confirm or create any theory that school size correlates to achievement, but does emphasize the desire of the public (in this case, the legislature of the state of Maine) and the academic community to know what impact, if any, school size really has on achievement (Silvernail, 2006).

Maine's Motivation for MLTI

When asked how Maine's laptop program came into being, Governor King said it started with a data point, three insights, and a lunch. The data point was that Maine was "stuck" in 37th place for per-capita income. The insights were 1) he did not know where the economy was going or what the jobs of the future would be, but they would probably involve two things: more education and technology, 2) if every state is trying to improve their economy and they are all using the same formula, how could Maine ever get out of 37th place—you do not get ahead by just keeping up, and 3) everything state governments do tends to be incremental; to make a difference, you have to make an improvement that is greater than incremental. The lunch was with Seymour Papert. When King asked how small should a student-to-computer ratio be, Papert told him that it does not matter how low your ratio is, it is only when it is one-to-one that the power occurs (King, 2006).

CHAPTER 3

METHODOLOGY

Data Source

History and Background of MLTI

In March 2000, Angus King, the governor of Maine, announced plans to equip all seventh and eighth grade students and teachers with a laptop, "a personal learning device" ("MLTI 2000 timeline", n.d.). In March 2002, the first 450-plus iBooks (Apple Macintosh laptop computers) were deployed to teachers and students in nine demonstration schools. Two thousand iBooks were issued to all seventh grade teachers in the state in June 2002. Two-day teacher trainings on effective ways to use technology for teaching were held throughout the state in July and August of 2002 and in August of 2002, over 17,000 iBooks were delivered to schools for all seventh grade students in the state ("MLTI 2002 timeline", n.d.). In January 2003, regional content area meetings were held for all seventh and eighth grade teachers and in April 2003, over 700 iBooks were delivered to all eighth grade teachers. Two-day trainings were held throughout that summer for all eighth grade teachers. In August 2003, all seventh and eighth graders began school with iBooks ("MLTI 2003 timeline", n.d.).

Participation in professional development opportunities for teachers was voluntary. After the first year, all professional development sessions were available to both seventh and eighth grade teachers which provided the opportunity for any teachers to participate who chose not to participate the first year, or any teachers who were new to the seventh or eighth grade (C. Brinkman, personal communication, December 5, 2006). The 2003-2004 school year marked the first group of students to have had access to laptop computers for two full school years (both seventh and eighth grade) in classrooms staffed by teachers who also had laptops and opportunity for training in using those laptops for learning in their classroom. It should be noted that teachers who teach both seventh and eighth grade had laptops for the same amount of time as the students in this study, but teachers who only teach eighth grade received laptops in the summer before the students in this study entered eighth grade. That means that in many classrooms, the students had one full year experience using technology while the teachers were in their novice year.

Note that the first 450 laptops issued in March 2002 went to seventh graders and their teachers in nine demonstration schools, called Exploration Schools. The intention was that they would have the laptops for only those 4 months of seventh grade, but Apple Computer, Inc. worked with the state and made it possible for those students to use those laptops for an additional year in the eighth grade. A few of the Exploration Schools were small enough that those students' seventh grade teacher was also their eighth grade teacher. Most of those students went on to an eighth grade classroom where all the students had a laptop (except for any students new to eighth grade that year) but who had a teacher or teachers who did not have any professional development in using the laptops in their classroom until the following year. A few were in larger schools where only a classroom or two was included in the Exploration Schools group. Those students had use of their laptop in eighth grade but were in classes where other students did not have laptops and with teachers who did not have professional development in laptops in the curriculum until the following summer (M. Muir, personal communication, July 26, 2006). Therefore, there is a very small group of students (less than 450 out of 17,000) who had laptops for 1 school year and 4 months before they took the eighth grade achievement test in spring 2003 and an even smaller group of students who had laptops for 1 school year and 4 months with a teacher who had professional development on the use of laptops in the classroom before they took the eighth grade achievement test. The current study looks at the class entering seventh grade in fall 2002, as it is the first group of Maine students to have nearly 2 full years of laptop usage in their classrooms with teachers who had the opportunity to take professional development and who also had technical and curricular support systems in place during both seventh and eighth grade.

Sources of Information on the Maine Learning Technology Initiative (MLTI)

The state of Maine, the Department of Education for the state, School Administration Districts (SAD), some individual schools, and teacher organizations in Maine have made attempts to report their findings and tell their stories about MLTI. In addition to reading and downloading many of these written documents to gather information about the state of teaching, learning, and technology in mathematics, informal interviews were also held with people familiar with the implementation of MLTI. One such interview was with Chris Brinkman, who serves as Technology Integration Specialist in Mount Blue Middle School, located in Farmington, Maine in SAD#9 which is the geographically largest SAD in the state, located in the southwest portion of the state of Maine. Brinkman was interviewed about the history of MLTI in his middle school.

Researchers from the University of North Texas and the University of Maine at Farmington who made MLTI school observation visits during the 2002-2003 time frame provided personal accounts as well as written materials to the author of this dissertation about technology-centered classroom activities during the time frame when learning activities whose outcomes would potentially be reflected in test scores would have taken place.

Additionally, five pre-service teachers who had completed a 6-week practicum in SAD#9 middle schools were interviewed during the fall of 2006. The pre-service teachers were sophomores at the University of Maine at Farmington studying to be teachers. Their first education class was the 12-credit-hour practicum block in which they took a 4-credit practicum course, a 4-credit-hour curriculum and assessment course, a 2-credit-hour classroom management course, and a 2-credit-hour technology integration course. During the practicum portion of this block of classes, these students spent all day Tuesday, Wednesday, and Thursday in a mentor teacher's classroom observing, tutoring individual or small groups of students, assisting the mentor teacher, and implementing at least one lesson. On Mondays and Fridays, they participated in their practicum course on campus where they prepared for, reflected on, and built on their classroom experiences. During the course of a 14-week semester, the students spent 2 weeks in orientation on the college campus, two 3-week periods in practicum, and two 3-week periods in the college classes. Of the 14 pre-service teachers in

Practicum Block 1, the 5 students who were specializing in middle and secondary mathematics teaching were the pre-service teachers chosen to be interviewed. Their observations were of one-to-one technology in the classroom during fall 2006 and are more reflective of the status of MLTI in its 4th year, rather than its 2nd year, which is the focus of the current study. However, their observations give general insights into the possibilities for one-to-one technology use in mathematics classrooms in the state of Maine.

Examples of Calculator Usage in Maine Eighth Grade Classrooms

One activity described by a pre-service teacher involved eighth-grade students recording the length of a standing broad jump and then repeating the exercise three additional times. They then calculated mean and standard deviation for their own jumps as well as for all the jumps of the members of their team of four. The students were encouraged to use non-graphing calculators to help in the calculations of standard deviation so that the focus was on the meaning and application of standard deviation and not on the mechanics of squaring, subtracting, and dividing numbers. Another activity had eighth-grade students comparing slope and y-intercept of a linear equation using a graphing calculator. The students observed changes in the values for slope and y-intercept and the subsequent graphs produced, and then formulated general rules for the line behavior with respect to slope and y-intercept. The value of the exercise as a pre-algebra lesson was for students to visually see the relationship of slope and y-intercept before moving to the abstract representations involved in the linear equations.

Examples of Laptop Usage in Maine Eighth Grade Classrooms

The four pre-service teachers who observed laptop usage in their classrooms described examples of how their mentor teachers used laptops as well as their own lessons that utilized the laptops. The examples are presented here using the categories of the Maine Educational Assessment (MEA) survey question, where possible. In the category of creating graphs, pre-service teachers reported usage of spreadsheet software to create charts or graphs of the data input into the spreadsheet. Additionally, some teachers used online graphing software to create and manipulate graphs.

In the category of getting data from the Web, one class was assigned a project of comparing cell-phone plans from at least three different cell phone service providers. The students then used this data to determine which plan was best for their needs. Cost of the phone, rebates for the phone's purchase price, number of minutes included in the plan, and cost of overage minutes were all considered. The students used the Web to research the data necessary to solve this problem. In another lesson concerning addition and subtraction of positive and negative integers, students used Google Earth (http://earth.google.com) to locate 10 cities on the map and determine the altitude of each city. Three of the assigned cities were located below sea level. Using this data gathered from the Web, students were given problems to solve that required the addition and subtraction of both positive (altitude of cities located above sea level) and negative (altitude of cities located below sea level) integers.

In the category of finding mathematics problems online, there were no examples given by the pre-service teachers. However, they did provide additional examples of laptop usage in the mathematics classroom that did not fit any of the categories provided on the state's annual assessment test and survey. These examples included usage of virtual manipulatives, online math tutoring services, online math tutorials, a WebQuest, and use of the software package titled "Geometer's Sketchpad," which is tool-based software that allows for the creation and manipulation of geometric constructions. Three of the pre-service teachers reported that their mentor teachers used the service Portaportal (http://portaportal.com) that allows a user to set up categories using a folder icon on a Web page and enter links to appropriate resources in the folders. Portaportal is a Web-based bookmarking utility similar to Delicious (http://del.icio.us). These online services are referred to as “social bookmarking” because one can tell a friend his/her user name and the friend can see all the bookmarks of the user. In this case, the teacher sets up the Web page and tells the student his/her user name and the students then go to the teacher's page where they easily find the categorized links posted by their teacher. One mentor teacher used this service quite extensively and tried to have at least two electronic resources available to students for every lesson taught in class, even if technology was not used in the classroom presentation of material. This process allowed students who were absent from class or needed assistance with a concept presented in class to receive additional help.

The Maine Educational Assessment (MEA) Standardized Achievement Test

The state of Maine issues the MEA on an annual basis to 4th, 8th, and 11th graders in all public schools, and, additionally, in some private schools. The MEA tests have been designed to measure status in performance against Maine's Learning Results (MLR) content standards for Reading, Writing, Mathematics, Science and Technology, Social Studies, Visual and Performing Arts, and Health. By law, schools were not required to implement the Learning Results content standards until the 2002-2003 school year ("Student test data profile: Public K-12 education in Maine", 2006).

The MEA administered to eighth graders in March 2004 marked the first statewide, standardized achievement test for the group of students who had laptops for 2 years in their classroom. In the eighth grade MEA of mathematics, survey questions were asked in addition to content assessment questions. These questions included:

> 1. Which statement best describes the use of calculators in your mathematics classes? A. Calculators are used daily. B. Calculators are used once or twice a week. C. Calculators are used once or twice a month. D. Calculators are rarely or never used.
>
> 2. What best describes the mathematics class you are taking in the eighth grade? A. basic mathematics B. pre-algebra C. Algebra I
>
> 3. Which statement best describes how you use your laptop in mathematics class: getting data from the Web, finding mathematics problems online, creating graphs? A. We do one of these. B. We do two of these. C. We do three of these. D. We do none of these. (2004, p. 219)

Results of these survey questions were reported as a percentage of the number of eighth grade students in each school that selected the given choice.

Data Acquisition

The MEA produces individual student results reported only to parents, but also produces summary results for schools and districts that are made public, called The

School Profile. The School Profile is an MEA report that presents summary scores for each school and district in the following content areas: Reading, Writing, Mathematics, Science and Technology, and Social Studies (2006).

The public results of the MEA are available in several formats that can be downloaded from the Internet, including an Excel spreadsheet of all the schools in the state at a given grade level. These statewide results, however, are not disaggregated by gender. The School Profiles provide data disaggregated by gender and are available in a Portable Document Format (PDF) for individual schools.

Two hundred fifteen of the 231 schools in Maine having an eighth grade had PDF files available for downloading with the results of the March 2004 administration of the MEA. The data was electronically extracted from the PDF using a Visual Basic program that identified items by object code as embedded in the internal code of each PDF file. The program then copied the data for that object into a tab-delimited file. Schools that did not report either an average female mathematics achievement score or an average mathematics achievement score (or both) were eliminated from the dataset. In a pilot study performed on the downloaded data from the first 48 schools (in alphabetical order), 6 schools (12.5%) fell into this category. Data was then coded to create variables that represented the extent or level of calculator use, the variety of laptop use, and the combined use of both, using the results of the corresponding survey questions. The tab-delimited file was then imported into Microsoft Excel 2004 for Macintosh.

During a pilot test, the data from the first 48 schools in alphabetical order (A through D) were entered manually into an Excel spreadsheet. Using that pilot test spreadsheet as a comparison, a data integrity test was carried out by comparing the extracted version of the first 48 schools to the hand-entered version of the first 48 schools. An Excel workbook was created with the hand-entered data copied into the first worksheet, the electronically extracted data copied and pasted into the second worksheet, and a comparison test was set up in the third worksheet. The comparison test consisted of subtracting the value in a cell on the first worksheet from the corresponding value in the second worksheet. If all cells in a row showed a value of zero, it was assumed that the values were the same in both the electronically extracted data and the hand-entered data for that school. Because values of zero were found in all 48 rows, it was determined that the electronically-extracted data were correctly extracted for the 48 schools for which there was a comparison and therefore assumed that the data were correct for the other schools for which there was no comparison.

Any schools that did not report disaggregated achievement scores for the girls (10 schools), or for the boys (10 schools), or for any students (12 schools) were removed from the data set. All 32 of these schools reported 15 or fewer eighth graders who took the achievement test. The data from the remaining 182 schools became the dataset for this study. These data were then opened in the statistical software package SPSS 11.0.3 for Macintosh OS X.

Each school in the state of Maine is assigned a unique number for identification purposes. In order to further validate the electronically extracted data, a frequencies analysis was carried out on these assigned numbers to insure no duplication of data existed. 182 unique numbers were reported, thus insuring no duplication of data.

Analysis was performed and figures were created using either SPSS or Excel software for Macintosh OS X. Effect size was calculated using Becker's (2000) online effect-size calculator for Cohen's *d* and effect size *r* using *t* values and degrees of freedom (separate groups *t* test).

Research Questions

The three key research questions for the current study are presented in this section. Each question contains a part a and part b subsection.

Extent of Calculator Use

Research Question 1a: Among public schools in the state of Maine, is eighth grade girls' mathematics achievement associated with a reported level of calculator usage?

Research Question 1b: Among public schools in the state of Maine, is eighth grade boys' mathematics achievement associated with a reported level of calculator usage?

Variety of Laptop Use

Research Question 2a: Among public schools in the state of Maine, is eighth grade girls' mathematics achievement associated with a reported variety of laptop usage?

Research Question 2b: Among public schools in the state of Maine, is eighth grade boys' mathematics achievement associated with a reported variety of laptop usage?

Combined Level of Use

Research Question 3a: Among public schools in the state of Maine, is eighth grade girls' mathematics achievement associated with the combined effect of variety of laptop usage and level of calculator usage?

Research Question 3b: Among public schools in the state of Maine, is eighth grade boys' mathematics achievement associated with the combined effect of variety of laptop usage and level of calculator usage?

Hypotheses

For the purpose of the current study, the following hypotheses were used. For each of the three areas of study there are two sub-areas, one for girls' mathematics achievement and one for boys' mathematics achievement. Additionally, there are both research and null hypotheses. The research hypotheses reflect the expectations based on Haskell's Theory of Transfer of Learning and the null hypotheses are presented as the status quo which will remain accepted in the event statistical analyses fail to confirm associations of magnitude ($p < .05$) hypothesized.

Extent of Calculator Use

Hypothesis 1a—Null

> Among public schools in the state of Maine, there is no association between eighth grade girls' mathematics achievement and the level of calculator usage in their school.

Hypothesis 1a—Research

> Among public schools in the state of Maine, the mathematics achievement of eighth grade girls is positively associated with the level of calculator usage in their school.

Hypothesis 1b—Null

Among public schools in the state of Maine, there is no relationship between eighth grade boys' mathematics achievement and the level of calculator usage in their school.

Hypothesis 1b—Research

Among public schools in the state of Maine, the mathematics achievement of eighth grade boys is positively associated with the level of calculator usage in their school.

Variety of Laptop Use

Hypothesis 2a—Null

Among public schools in the state of Maine, there is no relationship between eighth grade girls' mathematics achievement and the varied usage of laptops in their school.

Hypothesis 2a—Research

Among public schools in the state of Maine, the mathematics achievement of eighth grade girls is positively associated with the variety of laptop usage in their school.

Hypothesis 2b—Null

Among public schools in the state of Maine, there is no relationship between eighth grade boys' mathematics achievement and the varied usage of laptops in their school.

Hypothesis 2b—Research

Among public schools in the state of Maine, the mathematics achievement of eighth grade boys is positively associated with the variety of laptop usage in their school.

Combined Level of Use

Hypothesis 3a—Null

> Among public schools in the state of Maine, there is no relationship between the mathematics achievement of eighth grade girls and the linear combination of variety of laptop usage and level of calculator usage in their school.

Hypothesis 3a—Research

> Among public schools in the state of Maine, the mathematics achievement of eighth grade girls is positively associated with a linear combination of variety of laptop usage and level of calculator usage in their school.

Hypothesis 3b—Null

> Among public schools in the state of Maine, there is no relationship between the mathematics achievement of eighth grade boys and the linear combination of variety of laptop usage and level of calculator usage in their school.

Hypothesis 3b—Research

> Among public schools in the state of Maine, the mathematics achievement of eighth grade boys is positively associated with a linear combination of variety of laptop usage and level of calculator usage in their school.

Research Design

The research design for the current study was a pre-experimental, correlational design (Campbell & Stanley, 1966). School-wide average measures of two types of technology usage (calculators and laptops) were examined to determine the extent to which they were associated with school-wide averages of eighth grade mathematics achievement. Correlational analyses were performed separately for girls and boys. In addition, school-wide average demographic measures (school size and SES) were examined to determine the extent to which they were associated with school-wide averages of eighth grade mathematics achievement for girls and for boys. Partial correlations were also calculated to determine the association between math achievement and each technology usage while holding the effect of demographics constant. A similar analysis was used to assess the association between each school-wide technology measure and eighth grade mathematics achievement while the two demographic variables and the other technology measure were held constant. Regression analysis was used to test the third hypotheses, not for its predictive capabilities but because regression analysis is capable of providing strength of association indices between linear combinations of the two technology variables, (level of calculator usage and variety of laptop usage) and level of mathematics achievement. The procedure employed is conceptually equivalent to canonical correlation, which is designed to assess the association between two sets of variables, but the simpler linear regression was used because hypothesis 3 calls for a single variable (mathematics achievement) rather than a set of variables on the *y* side of the equation. Multiple variables on the *x* side are optimally combined by standard regression procedures (Garson, 2006).

The goal of a typical correlational research design is to accurately describe associations between events, rather than to attempt to infer causality. As pointed out by Campbell and Stanley (1966), " . . . causal interpretation of a simple or partial correlation depends upon both the presence of a compatible plausible causal hypothesis and the absence of plausible rival hypotheses to explain the correlation upon other grounds" (p. 65). In the Maine data there are numerous rival hypotheses for associations between technology and achievement that may be found, so inference of direction of causality was not attempted. Nevertheless, Campbell and Stanley (1966) also pointed out that data such as those in the current study " . . . are relevant to causal hypotheses inasmuch as they expose them to disconfirmation. If zero correlation is obtained, the credibility of the hypothesis is lessened" (p. 64). One goal of this study was to determine which indicators do, and do not, have meaningful associations with each other, among Maine's public schools with an eighth grade.

Effect size is a statistical index that "reflects the magnitude of an effect or the strength of a relationship" (American Psychological Association, 2001, p. 25). The American Psychological Association requires reporting effect size " . . .to provide the reader not only with information about statistical significance, but also with enough information to assess the magnitude of the effect or relationship" (American Psychological Association, 2001, p. 26). Bialo and Sivin-Kachala (1996) explain that

> According to Kulik and Kulik, an effect size of 0.30 constitutes a 'moderate but significant effect'; Ryan notes that an effect size of 0.30 is equivalent to approximately three months' gain in student achievement. Thus, an effect size of 0.30 or better in favor of technology-based instruction suggests such instruction is significantly effective . . . (p. 2).

Effect sizes are reported in the current study as an indicator of practical significance. Where possible, they are compared to the $ES = 0.30$ standard. For measures involving differences in mean scores between two groups, Cohen's d ($(\text{Mean}_2 - \text{Mean}_1)/\text{Pooled } SD$) is used.

Effect size guidelines provided by Cohen (1988) for Cohen's *d* are:

.2 = small

.5 = moderate

.8 = large

For measures involving associations between two continuous variables, effect size indicators other than Cohen's *d* are commonly used. Davis (1971) classified effect size descriptors for studies producing correlation coefficients as:

.70 or higher = very strong association

.50 to .69 = substantial association

.30 to .49 = moderate association

.10 to .29 = low association

.01 to .09 = negligible association

These two sets of guidelines, in addition to the more traditional measures of level of statistical significance ($p < .05$) and amount of variance in one indicator explained by another (r^2 in correlational analysis, R^2 in regression analysis), are the primary indices used to interpret the findings for this study.

Data Analysis

The variables used in the analyses were the average girls' mathematics achievement score and the average boys' mathematics achievement score for each school with an eighth grade, the extent of calculator usage for each school, the variety of laptop usage for each school, the size of the school (number of eighth graders enrolled on the first day of the MEA administration), and the number of economically-disadvantaged students. The default variable to identify economically disadvantaged eighth grade students in the state of Maine on the MEA is the National School Lunch Program (NSLP) variable (Measured Progress, 2004) which determines those students who are eligible for free or low-cost lunches. Because SES is known to have a large impact on student achievement (Boeck, 2002), it was important to include it in these analyses.

For each school, four numbers were reported in the MEA School Profile that represented calculator usage. There were four possible answers to the question, "Which statement best describes the use of calculators in your mathematics classes?" The percentage of students who selected an answer was reported for each of the four possible answers: A. Calculators are used daily. B. Calculators are used once or twice a week. C. Calculators are used once or twice a month. D. Calculators are rarely or never used. Choice D—rarely or never (calcnone) was coded as a 0. Choice C—once or twice a month (calcmon) was coded as a 1. Choice B—once or twice a week (calcweek) was coded as a 2. Choice A—daily (calcday) was coded as a 3. Because the data reported each variable as a percentage of students who chose that answer, the total was divided by 100 to create a proportion of 1.0. Using the following formula, level of calculator usage was coded for each school as a number on a scale from 0 to 3:

$$\text{calcuse} = [(0 * \text{calcnone}) + (1 * \text{calcmon}) + (2 * \text{calcweek}) + (3 * \text{calcday})] / 100$$

For each school, four numbers were reported in the MEA School Profile that were used to represent variety of laptop usage. There were four possible answers to the question, "Which statement best describes how you use your laptop in mathematics class: getting data from the Web, finding mathematics problems online, creating graphs?" For each of the four possible answers, the percentage of students who selected each answer was reported: none of these, one of these, two of these, or all three of these. Choice D—one of these (laptop0)—was coded as a 0. Choice A—one of these (laptop1)—was coded as a 1. Choice B—two of these (laptop2))—was coded as a 2. Choice C—three of these (laptop3))—was coded as a 3. Note that this question does not ask how often the laptops were used (level of laptop usage), but rather how many different ways the laptops were used (variety of laptop usage). Because the data reported each variable as a percentage of students who chose that answer, the total was divided by 100 to create a proportion of 1.0. Using the following formula, variety of laptop usage for each school was coded as a single number:

$$laptuse = [(0 * laptop0) + (1 * laptop1) + (2 * laptop2) + (3 * laptop3)] / 100.$$

CHAPTER 4

RESULTS

This chapter begins with descriptions of the 2003-2004 status of several variables playing key roles in the hypothesis tests presented later in the chapter. It ends with a summary of the key findings.

Girls' vs. Boys' Level of Mathematics Achievement

As shown in Figure 3, the range of school-wide averages of girls' mathematics achievement scores across all 182 schools was from 511 to 544 with a mean of 528.80 and a standard deviation of 5.209. The range of school-wide averages of boys' mathematics achievement scores, shown in Figure 4, was from 511 to 550 with a mean of 528.42 and a standard deviation of 5.785. Although the girls' average (528.80) is higher than the boys' average (528.42), the effect size of that difference is very small (d = .034); there is also no statistically significant difference (p = .266) between boys' and girls' average scores when using school as a unit of analysis. Nevertheless, the reported difference remains noteworthy because if these mean and standard deviation values had been produced directly from the approximately 8,000 girls and 8,000 boys summarized in the mean values for their schools, then eighth grade girls in Maine would have been judged to be significantly higher than boys in mathematics achievement at the p < .00002 level. This issue will be revisited in the Recommendations to Facilitate Future Studies Using Maine Learning Technology Initiative (MLTI) and Maine Educational Assessment (MEA) Data section of Chapter 5.

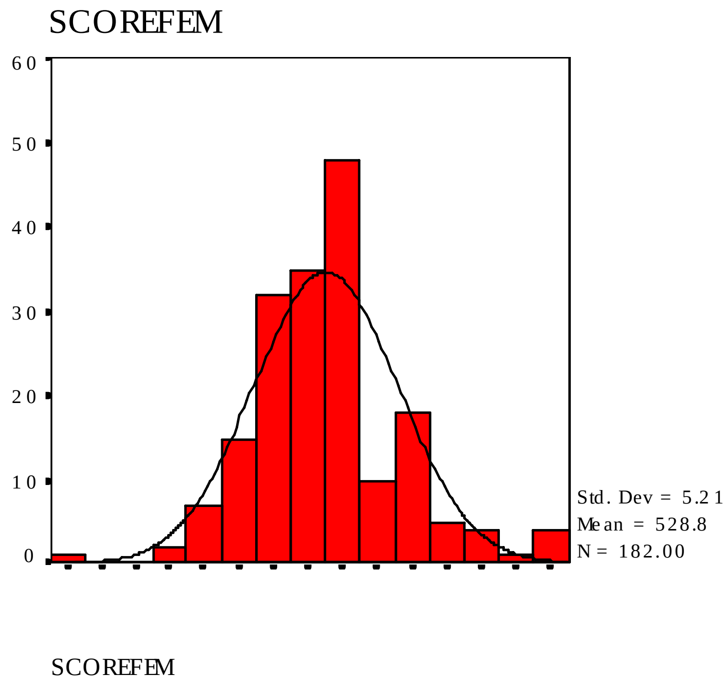

Figure 3. Distribution of school-wide averages of girls' mathematics achievement in schools with an eighth grade in the state of Maine.

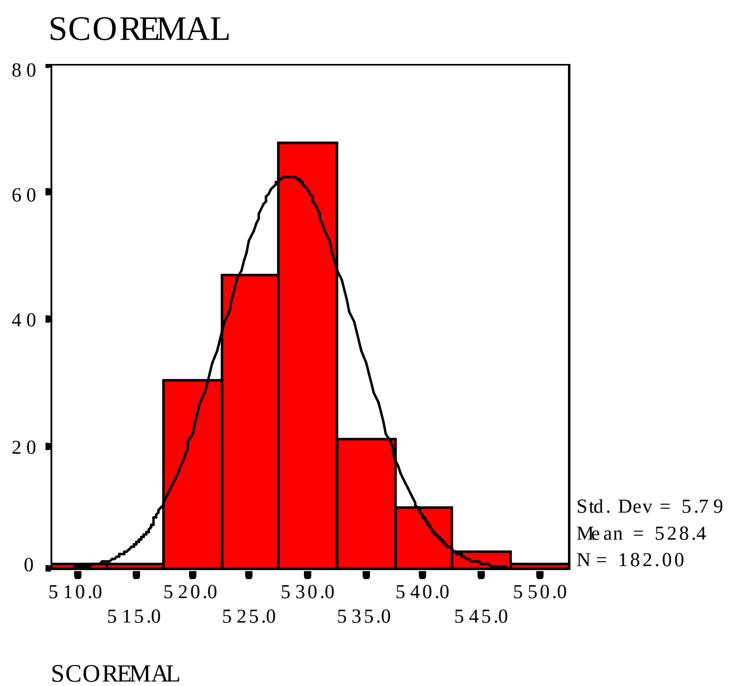

Figure 4. Distribution of school-wide averages of boys' mathematics achievement in schools with an eighth grade in the state of Maine.

Non-normal Distribution of School Size

Descriptive statistics for 182 schools with complete data were produced using the number of eighth grade students per school in attendance on the first day of the administration of the mathematics portion of the MEA. The number of eighth graders ranged from 10 to 353 with the mean being 88.97 students. Fifty percent of the schools had 61 or fewer students. Only 10.4% of the schools had over 200 students. As shown in Figure 5, there are many more small schools in Maine than there are large schools. The picture would be even more extreme if the 32 schools that were too small to report complete data (schools with less than 15 eighth graders) were also included.

Because these data were so heavily skewed, the data were normalized using the normalization function in the statistical software SPSS, in order to meet the assumptions required for correlation and partial correlation analyses. The normalized values TSCHLSIZ, shown in Figure 6, were therefore used in the analysis. The formula for the normalization process used was:

tschoolsize = natural logarithm (schoolsize).

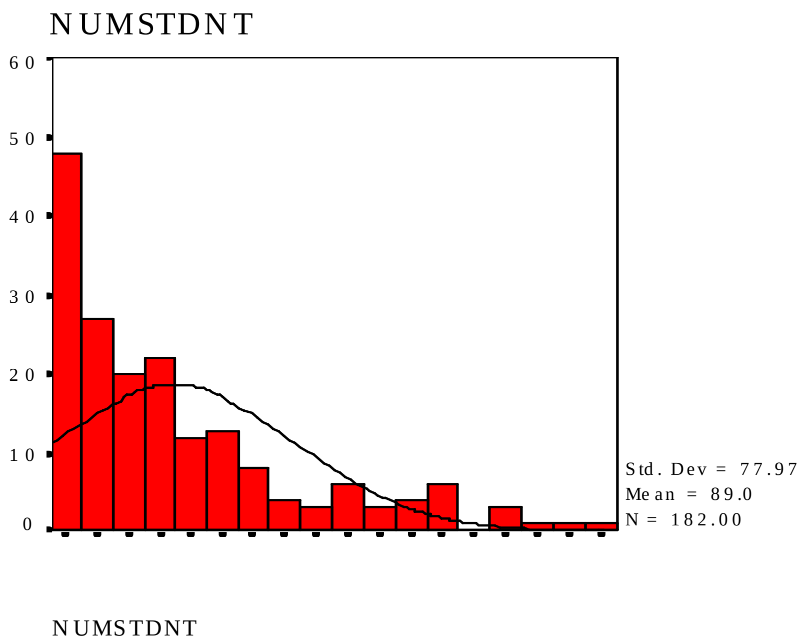

Figure 5. Distribution of schools by number of eighth grade students

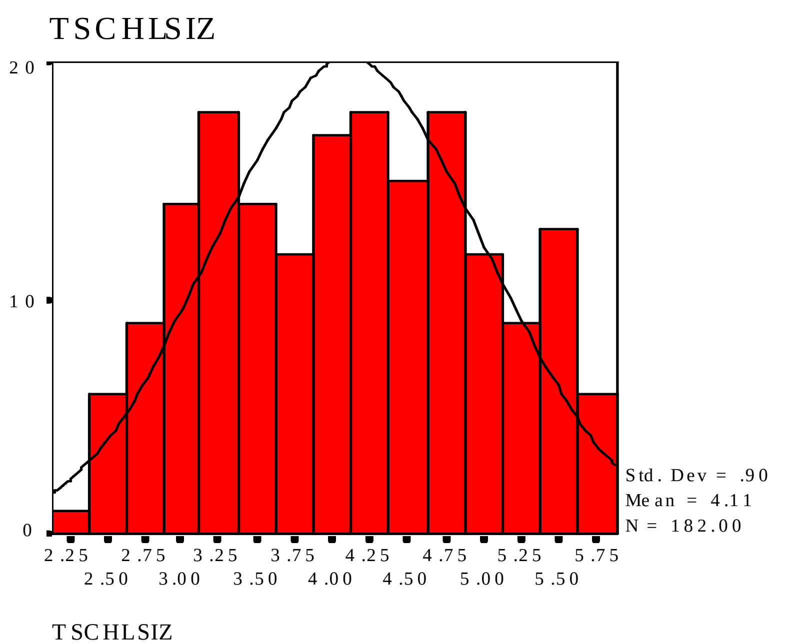

Figure 6. Normalized distribution of schools by number of eighth grade students.

Range of Socio-economic Status.

In the School Profiles, two of the reporting categories were "economically disadvantaged: yes" and "economically disadvantaged: no". The results were reported as the percentage of students in each category. When the two results are added together, the total is 100. Therefore, the possible range for economically-disadvantaged-yes is 0 to 100 where 0 represents a school with no economically disadvantaged students and 100 represents a school with all students being economically disadvantaged. The possible range for economically-disadvantaged-no is also 0 to 100, but 100 represents a school with all economically disadvantaged students and 0 represents a school with no students being economically disadvantaged. For ease of analysis, the non-economically disadvantaged result was used because of its similarity to the more commonly used socio-economic status (SES).

Of the 182 schools in the current study, 180 reported data on the percentage of students that were not economically disadvantaged. The 2 schools that did not report were small schools, 1 with 10 eighth grade students and 1 with 14 eighth grade students. As shown in Figure 7, of those 180 schools, the range was 0% to 100% with a mean of 70.33%. There was 1 school reporting 0% not economically disadvantaged students (all students in the school have a low SES). The next data point jumps to 31% not economically disadvantaged of which there is only one school. Twenty-two schools reported 100% not economically disadvantaged students (all of the students in the school have a high SES). A sizeable portion (12.2%) of the eighth grade classes in Maine schools were reported to have no economically disadvantaged students.

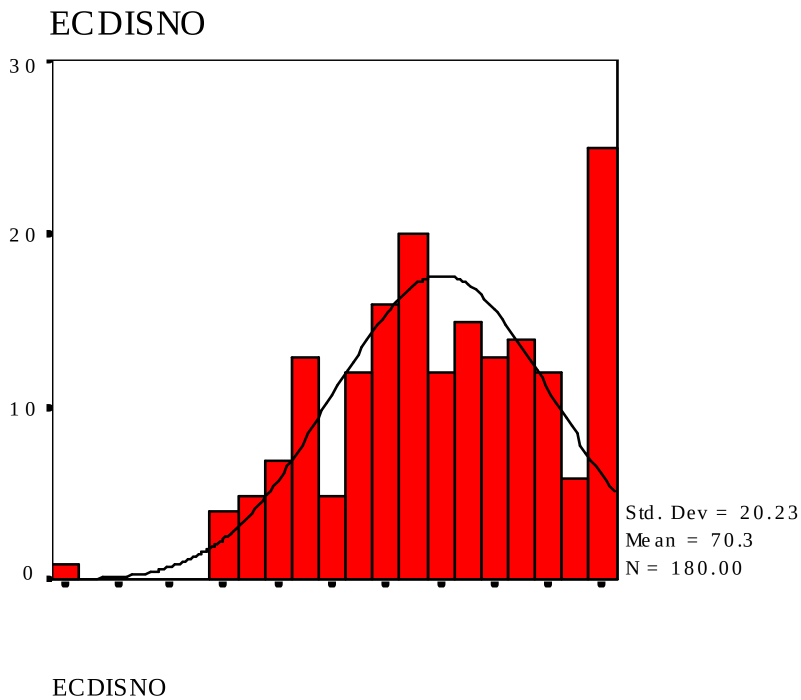

Figure 7. Distribution of percentage of students that are not economically disadvantaged in schools in Maine with an eighth grade.

Level of Calculator Usage

Each of the 182 schools in Maine with an eighth grade that was included in the current study was coded on a scale of 0 to 3 on the level of calculator usage in the mathematics classroom (where 0 is no calculator usage and 3 is daily usage). As shown in Figure 8, calculator usage ranged from 0.15 (where 0.0 represents that calculators are used rarely or never) to 3.00 (in 1 school, 100% of the students reported daily calculator usage in their mathematics class). The mean level of calculator usage was 1.85 and the standard deviation was 0.655. This falls between 1.0 (representing calculator usage once or twice a month) and 2.0 (representing calculator usage once or twice a week) but is closer to weekly calculator usage.

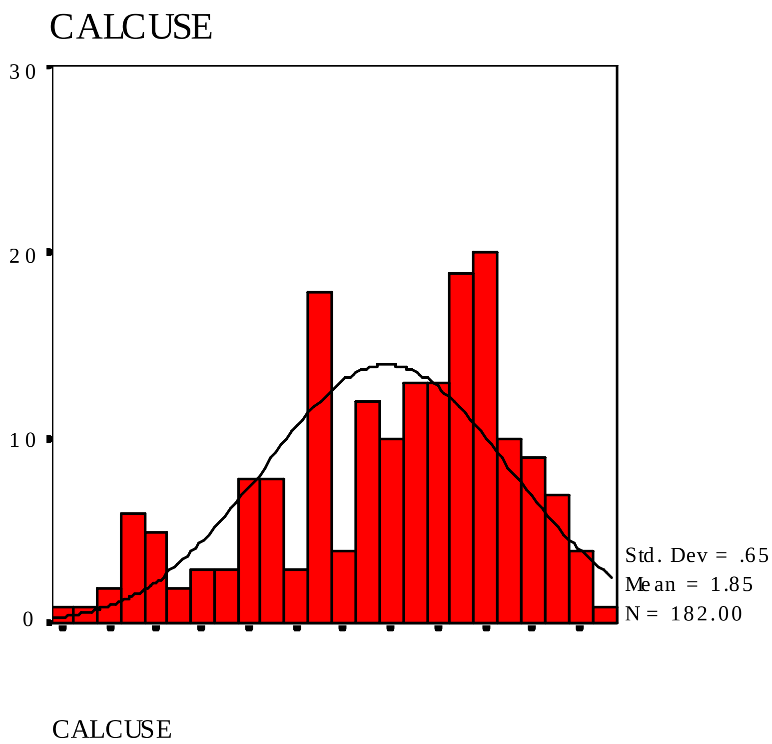

Figure 8. Distribution of level of calculator usage in schools in Maine with an eighth grade.

Variety of Laptop Usage

Similar to level of calculator usage, each school was coded on a scale of 0 to 3 on the variety of laptop usage in the mathematics classroom (where 0 is no laptop usage and 3 represents a classroom that uses laptops in all three of the possibilities from the three choices of ways laptops can be used in the classroom: getting data from the Web, finding mathematics problems online, creating graphs). As shown in Figure 9, variety of laptop usage ranged from 0.09 to 2.16. The mean variety of laptop usage was 0.99, which is essentially 1.0. This implies that of the three choices given, the average class used laptops in only one of the ways described. The standard deviation was 0.46.

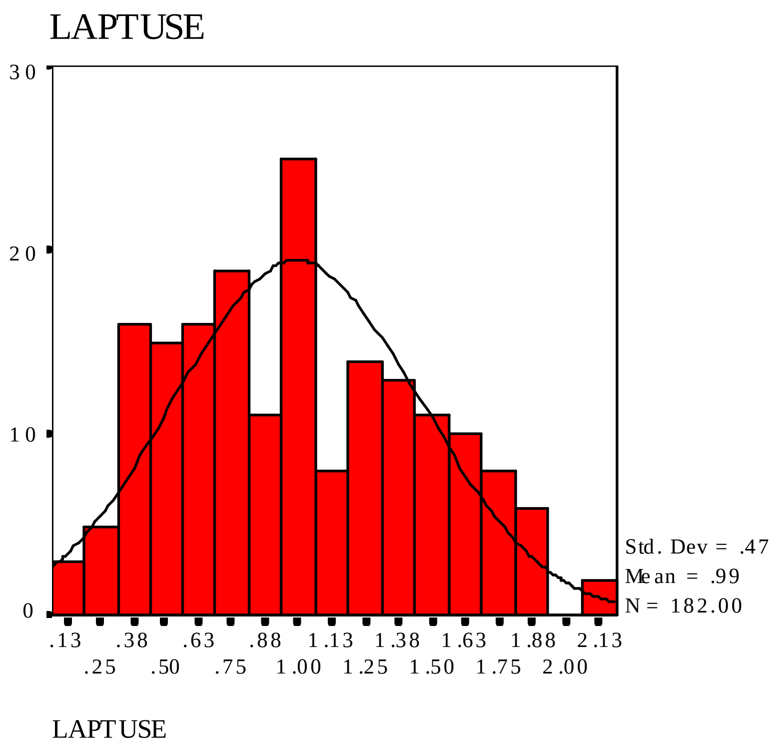

Figure 9. Distribution of variety of laptop usage in schools in Maine with an eighth grade.

Hypothesis Testing

Test of Hypothesis 1a: Association of Calculator Usage and Mathematics Achievement for Girls

Bivariate Correlation Analysis

The Pearson product moment correlation between the school-wide average level of calculator usage (n = 182) and the school-wide average of girls' mathematics achievement was .216 (p = .003). Roughly 5% (r^2 = .216 x .216 = .046) of the variance is common between level of calculator usage and average score for girls on mathematics achievement. Although this is considered to be a low association according to established guidelines (Davis, 1971), it is statistically significant at the pre-selected cutoff criterion of the $p < .05$ level. An association of this strength would have been very unlikely to have occurred by chance.

Partial Correlation Analysis

Partial correlations were produced for girls' mathematics achievement correlated with level of calculator usage, with the procedure controlling for the demographic variables of socio-economic status and school size. The partial correlation coefficient was .189 ($p = .011$), indicating that approximately 4% ($r^2 = .189 \times .189 = .036$) of the variance in girl's average level of mathematics achievement across schools could be explained by knowing average school-wide level of calculator use. Although this is considered a low association according to established guidelines (Davis, 1971), it is statistically significant at the $p < .05$ level. An association of this strength would have been very unlikely to have occurred by chance.

Partial correlations were also produced for girls' mathematics achievement correlated with level of calculator usage, when controlling for SES, school size, and variety of laptop usage. This is similar to the previous analysis except the second technology variable is added. The partial correlation coefficient was .194 ($p = .010$), indicating that approximately 4% ($r^2 = .194 \times .194 = .038$) of the variance in girl's average level of mathematics achievement across a school could be explained by knowing the school's average level of calculator use, after controlling for the effects of the two demographic variables and the other technology variable (variety of laptop use). Although this value is considered a low association according to established guidelines (Davis, 1971), it is statistically significant at the $p < .05$ level. An association of this strength would have been unlikely to have occurred by chance.

Conclusion Regarding Hypothesis 1a

Because significant ($p < .05$) associations were found between school-wide average level of calculator usage and school-wide average level of girls' mathematics achievement, even after controlling for the demographic variables of school size and SES, plus the technology variable variety of laptop usage, the null hypothesis of no association was rejected and the alternative hypothesis is confirmed. There is a positive association between average level of calculator usage in schools and average level of mathematics achievement for eighth grade girls in Maine.

Test of Hypothesis 1b. Association of Calculator Usage and Mathematics Achievement for Boys

Bivariate Correlation Analysis

The Pearson product moment correlation between the school-wide average level of calculator usage ($n = 182$) and the school-wide average of boys' mathematics achievement was .222 ($p = .003$). Roughly 5% ($r^2 = .222 \times .222 = .049$) of the variance is common between level of calculator usage and average score for boys on mathematics achievement. Although this is considered a low association according to established guidelines (Davis, 1971), it is statistically significant at the pre-selected cutoff criterion of the $p < .05$ level. An association of this strength would have been very unlikely to have occurred by chance.

Partial Correlation Analysis

Partial correlations were produced for boys' mathematics achievement correlated with level of calculator usage, when controlling for the demographic variables of SES and school size. The partial correlation coefficient was .194 ($p = .010$), indicating that approximately 4% ($r^2 = .194 \times .194 = .038$) of the variance in boy's average level of mathematics achievement across schools could be explained by knowing average school-wide level of calculator use. Although this is considered a low association according to established guidelines (Davis, 1971), it is statistically significant at the $p <$ .05 level. An association of this strength would have been unlikely to have occurred by chance.

Partial correlations were also produced for boys' mathematics achievement correlated with level of calculator usage, when controlling for SES, school size, and variety of laptop usage. This is similar to the previous analysis except the second technology variable is added. The partial correlation coefficient was .193 ($p = .010$), indicating that approximately 4% ($r^2 = .193 \times .193 = .037$) of the variance in boy's average level of mathematics achievement across a school could be explained by knowing the school's average level of calculator use, after controlling for the effects of the two demographic variables and the other technology variable. Although this value is considered a low association according to established guidelines (Davis, 1971), it is statistically significant at the $p < .05$ level. An association of this strength would have been very unlikely to have occurred by chance.

Conclusion Regarding Hypothesis 1b

Because significant ($p < .05$) associations were found between school-wide average level of calculator usage and school-wide average level of boys' mathematics achievement, even after controlling for the demographic variables of school size and SES, plus the technology variable variety of laptop usage, the null hypothesis of no association is rejected and the alternative hypothesis is accepted. There is a positive association between average level of calculator usage in schools and average level of mathematics achievement for eighth grade boys in Maine.

Test of Hypothesis 2a. Association of Laptop Usage and Mathematics Achievement for Girls

Bivariate Correlation Analysis

The Pearson product moment correlation between the school-wide average variety of laptop usage ($n = 182$) and the school-wide average of girls' mathematics achievement was .030 ($p = .683$). Less than 1% ($r^2 = .030 \times .030 = .0009$) of the variance is common between variety of laptop usage and average score for girls on mathematics achievement. This is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the pre-selected cutoff criterion of the $p < .05$ level.

Partial Correlation Analysis

Partial correlations were produced for girls' mathematics achievement correlated with variety of laptop usage, when controlling for the demographic variables of SES and school size. The partial correlation coefficient was -.030 (p = .692), indicating that less than 1% (r^2 = .030 x .030 = .0009) of the variance in girl's average level of mathematics achievement across schools could be explained by knowing average school-wide variety of laptop use. This is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the $p < .05$ level.

Partial correlations were also produced for girls' mathematics achievement correlated with variety of laptop usage, when controlling for socio-economic status, school size, and level of calculator usage. This is similar to the previous analysis except the second technology variable is added. The partial correlation coefficient was -.054 (p = .478), indicating that less than 1% (r^2 = .054 x .054 = .003) of the variance in girl's average level of mathematics achievement across a school could be explained by knowing the school's average variety of laptop use, after controlling for the effects of the two demographic variables and the other technology variable (calculator use). This value is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the $p < .05$ level.

Conclusion Regarding Hypothesis 2a

Because no statistically significant ($p < .05$) associations were found between school-wide average variety of laptop usage and school-wide average level of girls' mathematics achievement, the null hypothesis of no association cannot be rejected. There is insufficient evidence to conclude that variety of laptop usage as measured by the MEA is related to mathematics achievement for eighth grade girls in Maine.

Test of Hypothesis 2b. Association of Laptop Usage and Mathematics Achievement for Boys

Bivariate Correlation Analysis

The Pearson product moment correlation between the school-wide average variety of laptop usage (n = 182) and the school-wide average of boys' mathematics achievement was .081 (p = .275). Less than 1% (r^2 = .081 x .081 = .007) of the variance is common between variety of laptop usage and average score for boys on mathematics achievement. This is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the pre-selected cutoff criterion of the $p < .05$ level.

Partial Correlation Analysis

Partial correlations were produced for boys' mathematics achievement correlated with variety of laptop usage, when controlling for the demographic variables of SES and school size. The partial correlation coefficient was .019 (p = .804), indicating that less than 1% (r^2 = .019 x .019 = .0004) of the variance in boy's average level of mathematics achievement across schools could be explained by knowing average school-wide variety of laptop use. This is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the $p < .05$ level.

Partial correlations were also produced for boys' mathematics achievement correlated with variety of laptop usage, when controlling for SES, school size, and level of calculator usage. This is similar to the previous analysis except the second technology variable is added. The partial correlation coefficient was -.004 (p = .955), indicating that less than 1% (r^2 = .004 x .004 = .00002) of the variance in boy's average level of mathematics achievement across a school could be explained by knowing the school's average variety of laptop use, after controlling for the effects of the two demographic variables and the other technology variable. This value is considered less than a negligible association according to established guidelines (Davis, 1971) and is not statistically significant at the $p < .05$ level.

Conclusion Regarding Hypothesis 2b

Because no significant ($p < .05$) associations were found between school-wide average variety of laptop usage and school-wide average level of boys' mathematics achievement, even after controlling for the demographic variables of school size and SES, plus the technology variable variety of laptop usage, there is no basis for rejecting the null hypothesis of no association between school-wide average boys' mathematics achievement scores and variety of laptop usage in eighth grade public schools in the state of Maine.

Test of Hypothesis 3a. Association of Calculator and Laptop Usage Combined and Mathematics Achievement for Girls

Regression analysis was used to test this hypothesis because it is capable of providing strength of association indices between linear combinations of the two technology variables (level of calculator usage and variety of laptop usage) and level of mathematics achievement. As shown in Table 2, the total percentage of variance (R^2) in mathematics achievement accounted for by a linear combination of level of calculator usage and variety of laptop usage was .132. Thus, the four variables (SES, school size, calculator use, and laptop use) featured in this study account for approximately 13% of the variance in the average school-wide mathematics achievement score for eighth grade girls. Socio-economic status, with a standardized Beta (β) of .26 accounts for the largest portion of that variance. Level of calculator usage has a β of .174 and accounts for the second largest variance. Both SES and level of calculator usage have statistically significant ($p < .05$) associations with mathematics achievement for girls; both have an effect size greater than .30 which shows that both association of SES with girls' mathematics achievement and association of level of calculator usage with girls' mathematics achievement are educationally meaningful (Bialo & Sivin-Kachala, 1996), according to established guidelines. Neither school size ($p = .148$) nor variety of laptop usage ($p = .724$) accounted for variance in girls' mathematics achievement scores at a statistically significant level.

Table 2

Summary of Linear Regression Analysis for Girls' Mathematics Achievement for 180 Maine Schools with Eighth Grade

	Unstandardized Coefficient *B*	*SE*	β	*t*	*p*	*d*
(Constant)	519.472	2.447		212.299	.000	
TSCHLSIZ	.603	.415	.104	1.454	.148	.216
CALCUSE	1.405	.577	.174	2.435	.016	.362
LAPTUSE	-.280	.793	-.025	-.353	.724	-.052
ECDISNO	6.313E-02	.018	.260	3.572	.000	.531

Note. Dependent variable: SCOREFEM

Conclusion Regarding Hypothesis 3a

Because significant ($p < .05$) associations were found between girls' mathematics achievement and a linear combination of the variables level of calculator usage and variety of laptop usage, while holding other key variables constant, the null hypothesis of no association is rejected and the alternative hypothesis is accepted. There is a positive association between the linear combination of level of calculator usage and variety of laptop usage for eighth grade girls in schools in the state of Maine, with the note that variety of laptop usage contributes very little (β = -.025) to the linear combination.

Test of Hypothesis 3b. Association of Calculator and Laptop Usage Combined and Mathematics Achievement for Boys

Regression analysis was used to test this hypothesis as it was for hypothesis 3a. The total percentage of variance (R^2) in mathematics achievement accounted for by a linear combination of level of calculator usage and variety of laptop usage was .115. Thus, the four variables (SES, school size, calculator use, and laptop use) featured in this study account for approximately 12% of the variance in the average school-wide mathematics achievement score for eighth grade boys. As shown in Table 3, SES, with a standardized Beta (β) of .244 accounts for the largest portion of that variance. Level of calculator usage has a β of .176 and accounts for the second largest variance. Both SES and level of calculator usage have statistically significant ($p < .05$) associations with mathematics achievement for boys; both have an effect size greater than .30 which indicates that both the association of SES with boys' mathematics achievement and level of calculator usage with boys' mathematics achievement are educationally meaningful (Bialo & Sivin-Kachala, 1996), according to established guidelines. Neither school size ($p = .588$) nor variety of laptop usage ($p = .658$) accounted for variances at a statistically significant level in boys' mathematics achievement scores.

Table 3

Summary of Linear Regression Analysis for Boys' Mathematics Achievement for 180 Maine Schools with Eighth Grade

	Unstandardized Coefficient *B*	*SE*	β	*t*	*p*	*d*
(Constant)	519.472	2.447		212.299	.000	
TSCHLSIZ	.252	.465	.039	.542	.588	.081
CALCUSE	1.580	.647	.176	2.442	.016	.363
LAPTUSE	.395	.890	.032	.444	.658	.066
ECDISNO	6.598E-02	.020	.244	3.328	.001	.495

Note. Dependent variable: SCOREMAL

Conclusion Regarding Hypothesis 3b

Because significant ($p < .05$) associations were found between boys' mathematics achievement and a linear combination of the variables school-wide average level of calculator usage with variety of laptop usage, while holding all other variables constant. The null hypothesis of no association is rejected and the alternative hypothesis is confirmed. It is concluded that there is a positive association between the linear combination of level of calculator usage and variety of laptop usage for eighth grade boys in schools in the state of Maine, while also noting that the variety of laptop usage contributes very little ($\beta = .032$) to the linear combination.

Post-hoc Exploration of Gender Differences in Technology Usage and Mathematics Achievement

When looking at average girls' math achievement score (528.80) across schools vs. average boys' math achievement score (528.42) across schools, there is a difference of 0.38 points, which translates to an effect size (Cohen's *d*) of .07. This effect size is less than small (Cohen, 1988) and there is no statistically significant ($p < .05$) difference overall between girls' and boys' mathematics achievement score on a school-as-unit-of-study (n = 182) basis. However, there did appear to be a trend toward girls being higher. In order to further explore that trend, the average mathematics score of all eighth grade students in the school without regard to gender was calculated, and then the schools were ranked by school-wide average mathematics score to determine a performance level of mathematics achievement by school. The top 25% of those schools (n = 45) were then analyzed for gender differences. The difference between the average girls' mathematics achievement score and the boys' score was 0.02 (d = -.004) with the boys having the slightly higher score. A case-by-case examination revealed that in 7 of the 45 schools, the boys' and the girls' school average mathematics achievement scores were equal. In 19 of the 45 schools, the girls' average mathematics score for the school was higher than the boys' average mathematics score and in the remaining 19 schools the boys' average mathematics score was higher than the girls' average mathematics score. A Sign Test run via SPSS produced an Asymptotic Significance (2-tailed) of 1.00 showing this distribution to be near to exactly what would be expected by chance. There is no indication of difference in the girls' average score and the boys' average score in mathematics achievement in the top 25% of schools in the state of Maine.

In performing the same analyses on the bottom 25% of the schools in the state of Maine rank ordered by school-wide average mathematics achievement score (n = 45), the difference between the average girls' mathematics score and the boys' score was 1.49 points. This difference, divided by the pooled standard deviation (3.323) produced a moderate effect size (d = .447), with the girls having the higher score. A case-by-case examination revealed that in 6 of the 45 schools, the boys' and the girls' school-wide average in mathematics achievement were equal. In 28 of the 45 schools, the girls' average mathematics score for the school was higher than the boys' average mathematics score and in the remaining 11 schools the boys' school-wide average mathematics score was higher than the girls' average mathematics score. Cohen's d of .447 (for difference between girls' and boys' school-wide average mathematics achievement score) is considered educationally meaningful (Bialo & Sivin-Kachala, 1996). A sign test run via SPSS produced an asymptotic significance (2-tailed) of .01, which is statistically significant at the $p < .05$ level. Additionally, when investigating the upper and lower 25% of schools with an eighth grade in the state of Maine based on average mathematics achievement scores, the difference in calculator usage was statistically significant (d = .594) with the higher performing schools having a mean level of calculator usage of 2.069 (on a scale of 0 to 3) and the lower performing schools having a mean level of calculator usage of 1.698.

It appears there is gender equity in mathematics achievement in the top performing eighth grade schools in the state of Maine but not in the lower performing eighth grade schools. The boys’ school-wide average mathematics achievement score is lower than the girls’ school-wide average mathematics achievement score in lower performing schools.

Summary of Findings

Although eighth grade girls' and boys' math achievement scores were not found to be significantly ($p < .05$) different when using school-as-a-unit-of-analysis, the difference in favor of girls might have been statistically significant if the same mean and standard deviation values resulted from 8,000 individual girls and 8,000 individual boys, rather than aggregates from 182 schools.

In a post-hoc analysis of findings, schools were rank ordered based on the average mathematics achievement score regardless of gender; the top 25% (n = 45) and the lower 25% of the schools were evaluated. In the top 25%, there was no statistically significant difference between school-wide girls' mathematics achievement score and school-wide boys' mathematics achievement score. In the highest performing schools, relative to mathematics achievement, girls and boys performed equally as well on the mathematics achievement test. However, in the lower 25% of the schools, there was a statistically significant difference (p = .01) between the school-wide average of girls' mathematics achievement score and boys' mathematics achievement score, with girls performing better than the boys on the achievement test. The school-wide girls’ mathematics achievement score in this category was 1.49 points higher (p = .01, d = .447) than the boys'.

The major results for the hypotheses listed in Chapter 3 were:

Hypothesis 1: Confirmed that level of calculator usage is associated with mathematics achievement for girls (r = .189, p = .011) and boys (r = .194, p = .010).

Hypothesis 2: Failed to confirm that variety of laptop usage was associated with mathematics achievement for either girls or boys, and

Hypothesis 3: Confirmed that the linear combination of level of calculator usage and variety of laptop usage was associated with mathematics achievement for girls (β = -.025) and boys (β = .032).

Implications of these findings will be addressed in Chapter 5.

CHAPTER 5

SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Summary of Hypothesis Testing

As summarized in Table 4, correlational analysis showed that there was a statistically significant (r = .189, p = .011) association between school-wide average of girls' mathematics achievement scores on the Maine Educational Assessment (MEA) and the level of calculator usage in their school. Null hypothesis 1a was therefore rejected and the research hypothesis was accepted, confirming a positive association between calculator usage and mathematics achievement for eighth grade girls in the state of Maine. Similarly, there was a statistically significant (r = .194, p = .010) association between school-wide average of boys' mathematics achievement scores and the level of calculator usage in their school. Null hypothesis 1b was rejected and the research hypothesis was accepted, confirming a positive association between calculator usage and mathematics achievement for eighth grade boys in the state of Maine.

No statistically significant (p < .05) association between school-wide average of girls' mathematics achievement scores and the variety of laptop usage in their school was found, thus null hypothesis 2a failed to be rejected. In addition, no statistically significant (p < .05) association between school-wide average of boys' mathematics achievement scores and the variety of laptop usage in their school was found so null hypothesis 2b failed to be rejected.

A statistically significant (β = .174, p = .016) association between school-wide average of girls' mathematics achievement scores and the linear combination of level of calculator usage and variety of laptop usage was found. Therefore, null hypothesis 3a was rejected and the alternative was accepted. In addition, a statistically significant ($\beta = .176$, $p = .016$) association between school-wide average of boys' mathematics achievement scores and the linear combination of calculator usage and variety of laptop usage was found. Therefore, null hypothesis 3b was also rejected and the alternative was accepted.

It is important to note that because variety of laptop usage was so weakly associated with either girls' or boys' school-wide average mathematics achievement scores that the level of calculator usage was the only real factor in the linear combination of the two technology variables. Therefore, the linear combination as a variable is weak. Therefore, even though null hypothesis 3 for both girls and boys can be rejected on a statistical basis, because the variety of usage variable is so weak, the linear combination was not effectively tested in the current study.

Table 4

Summary of Hypothesis Testing

Null Hypothesis	a. Girls' mathematics achievement	b. Boys' mathematics achievement
1. In the state of Maine, there is no association between eighth grade math achievement and level of calculator usage.	1a. Reject	1b. Reject
2. In the state of Maine, there is no association between eighth grade math achievement and varied usage of laptops	2a. Fail to reject	2b. Fail to reject
3. In the state of Maine, there is no association between eighth grade math achievement and a linear combination of varied usage of laptops and level of usage of calculators.	3a. Reject	3b. Reject

Variety of laptop usage had a less than negligible association with mathematics achievement for either boys or girls. Though Pearson Correlations of -.054 for girls and -.004 for boys are not educationally meaningful effect sizes according to established guidelines (Bialo & Sivin-Kachala, 1996), variety of laptop usage should be flagged as a factor to watch in future years of MLTI to ensure that laptop usage does not become negatively associated with mathematics achievement for either girls or boys.

Implications of Findings Regarding Transfer of Learning

Haskell (2001), defines transfer of learning as "how previous learning influences current and future learning, and how past or current learning is applied or adapted to similar or novel situations" (p. 23). Applying that definition to eighth graders in Maine, the mathematics concepts successfully taught utilizing calculators could be considered the past learning and the multiple choice or constructed response items on the mathematics achievement test could be considered similar or novel situations. The association between level of calculator usage and school-wide averages of mathematics achievement scores for both girls and boys could imply that continued and possibly increased use of calculators as a tool for meaningful mathematics teaching could contribute to near transfer of learning of mathematics concepts. More studies need to be conducted to ascertain if this is indeed true and if there are other confounding variables.

Comparison of Findings to Previous Studies

According to *Technology in American Schools: Seven Dimensions for Gauging Progress* (C. Lemke & Coughlin, 1998), under the right conditions technology:

- Accelerates, enriches and deepens basic skills
- Motivates and engages students in learning

- Helps relate academics to the practices of today's work force
- Increases economic viability of tomorrow's workers
- Strengthens teaching
- Contributes to change in schools
- Connects schools to the world (p. 3)

Findings in the current study related to calculator usage appear to be consistent with the first of the points made by Lemke and Coughlin about accelerating learning and enriching basic skills. Use of calculators in Maine schools for eighth graders is clearly associated with mathematics achievement. Lemke and Coughlin's point of increasing economic viability of tomorrow's workers is consistent with Governor King's original objective for introducing the concept of the Maine Learning Technology Initiative (MLTI).

Dunleavy and Heineke (in press) used a pre-post treatment and control group design to study the impact of one-to-one laptops in middle school science and mathematics in Virginia. They found there were no significant main effects or interaction effects of the one-to-one treatment on mathematics posttest scores after partialing out pre-existing mathematics achievement differences with a covariate. The results of the study are generally consistent with those found elsewhere in Virginia–no impact of laptops on mathematics achievement scores–and are consistent with the findings of this study related to laptop usage.

Muir, Knezek, and Christensen (2005) found in their initial study of MLTI that though there was no significant difference before laptop usage at the Exploration

Schools compared to the other schools with eighth grade (*ES* = .03), there was a difference in favor of the Exploration Schools on MEA scores after the first 4 months of laptop usage, though it had a small effect size (*ES* = .21). These findings are dissimilar from the findings of the current study in which there was no association between laptop usage and mathematics achievement.

Recommendations to Facilitate Future Studies Using MLTI and MEA Data

Data Disaggregation Issues

Where no strong association was found between mathematics achievement and the technology variable of variety of laptop usage, one should not necessarily conclude that the association does not exist. Rather, these results may be more a reflection of the data at hand. If one were to carry out a similar analysis with data disaggregated by classroom, one might get a better view of the use of technology (calculators, laptops, or both) in that classroom, which is the unit in which it is implemented. Some schools in the state of Maine are small enough that there is only one eighth grade class in the whole school, but in schools with multiple eighth grade classes, especially with different levels of mathematics classes, an average score to represent the entire school may not accurately reflect the diversity of teaching, learning, or technology usage that is occurring in that school. It would likewise be more effective to use data disaggregated by gender when looking for associations between math achievement by gender and the use of technology, since a school average or class average of perceived technology usage does not reflect the girls' perception vs. the boys' perception.

A second area where data disaggregation was an issue was current course enrollment. This is known to have an effect on mathematics achievement test scores. Muthén and Burstein (1991) demonstrated that some test items have a much higher rate of being answered correctly depending on a student's "opportunity-to-learn". Only 20.8% of the eighth grade students in the state reported being enrolled in a basic mathematics course (see Figure 10) but there was at least one basic mathematics student in 162 of the 182 schools. Only 6 schools reported more than half of the students in a basic mathematics class. There were 2 schools that reported exactly half of the students in a basic mathematics class. The remaining 174 schools all had fewer than half of their students in basic mathematics. It was not possible to disaggregate the data by course enrollment in this study. A replication study of Muthén and Burstein's work could be run with the MEA data if it were run on the data of individual students or the data disaggregated by classroom.

The eighth grade mathematics MEA focuses on the content from the pre-algebra class (Measured Progress, 2004). However, 25.3% of students felt that the MEA matched little or none of what they were learning in class (see Figure 11). If 20.8% of those students can be accounted for feeling as they do because they were enrolled in basic mathematics and not pre-algebra or algebra, who are the other 4.5% and are there any trends in gender, SES, or school size among those students? It is possible that gender differences are masked by the course enrollment. If data were disaggregated by classroom rather than by school, a study could be done on technology and mathematics achievement by gender in classes studying pre-algebra or algebra vs. those studying basic mathematics.

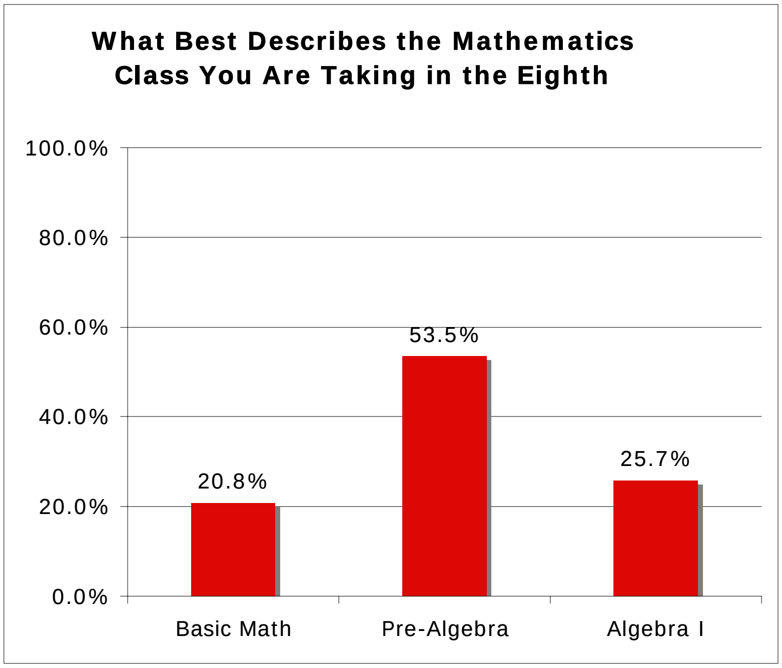

Figure 10. Distribution of eighth grade student responses in the state of Maine (n = 16,458) of their current course enrollment.

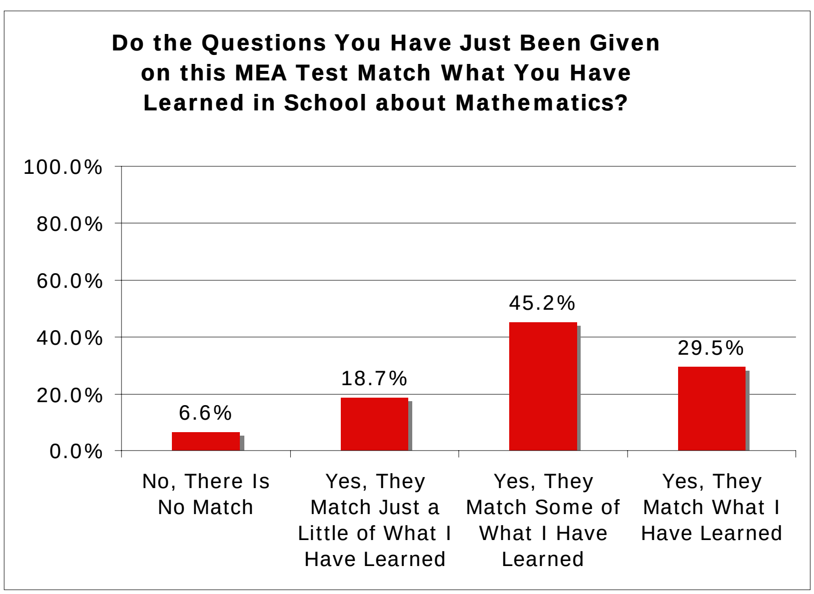

Figure 11. Distribution of eighth grade student responses in the state of Maine (n = 16,458) concerning their perception of how well the MEA achievement test items matched what they had learned in their mathematics class.

Access to Question Types and Categories of Content Type

Calvert and Engelhard (2000) cite Tate (1997) and Willingham and Cole (1997) when they warned that the nature of gender differences can be masked when comparing mean scores. They had access to individual item responses on the Second International Mathematics and Science Study and were able to analyze gender differences in specific sub-categories of mathematics achievement question types. Such data were not available from the state of Maine in the School Profiles, but the MEA Technical Handbook (Measured Progress, 2004) describes that questions are coded as to which cluster level the question addresses: numbers and operations, shape and size (geometry and measurement), mathematical decision making (data analysis and statistics, probability, and mathematical reasoning), and patterns (patterns, relationships and functions; algebra concepts; and mathematical communication). One could use the MEA data and replicate Tate and Willingham and Cole's studies. One could also look at item type: multiple choice, short answer, or constructed response to further expand on Beller and Gafni's (Beller & Gafni, 2000) work in the area of test item format and item difficulty. One could also use this rich data set to delve further into Kilpatrick, Swafford, and Findell's (2001) work that use of graphing calculators was associated with superior attainment by all students on symbolization items but investigate gender differences by items to determine if girls in Maine with greater calculator usage would outperform the boys as was the case in Great Britain.

Validity of Laptop Usage Measure

The results presented in this document are also a reflection of the measurement tool. A mathematics class that used laptops three times in an entire year, once for graphing, once for finding mathematics problems online, and once for getting data from the Web is coded as a 3.0. A mathematics class that used laptops for getting data from the Web on a regular basis in an effort to study meaningful, relevant, and current applications of the mathematics being studied and did so on a regular basis, but did not use their laptops for graphing or finding problems online is coded as a 1.0. And yet on a scale of 0 to 3 the former classroom would be rated higher than the latter indicating more or better laptop usage by the class with trivial usage vs. the class with in-depth, meaningful usage. The current measure "variety of laptop usage" is not a good indicator of either the quality or the quantity of pedagogically appropriate laptop usage in a mathematics classroom.

Currently there is one survey question about the three different types of laptop usage in the mathematics classroom. A better evaluation of the use of laptops could be made by creating three questions, one for each of the three categories of purpose. For example, one question could be: Which statement best describes the use of laptops for the purpose of finding mathematics problems on the Web in your mathematics classes? The choices would be: A. Laptops are used daily for finding math problems on the Web. B. Laptops are used once or twice a week for finding math problems on the Web. C. Laptops are used once or twice a month for finding math problems on the Web. D. Laptops are rarely or never used for finding math problems on the Web. The second question would ask about using the laptop for the purpose of creating graphs with the same choices of daily, weekly, monthly, and rarely or not at all. The third question would ask about using the laptop in the mathematics class for the purpose of getting data from the Web. With these three questions, a researcher could better determine how often laptops are used in the classroom (level of laptop usage) as well as for what purpose.

The interviews with pre-service teachers revealed that the three categories described in the survey question may not capture the possibilities of laptop usage in mathematics classrooms in the state of Maine. Even though the pre-service teachers did not observe any laptop usage in the area of finding problems on the Web, it is possible that other classes in the state of Maine are using their laptops in their mathematics class to find problems on the Web. However, the fact that the pre-service teachers gave examples of laptop usage not covered in the three categories suggests that the State may wish to reconsider the categories. A quick survey of some mathematics teachers could reveal additional categories (WebQuests, mathematics tutorials, Geometer's Sketchpad software) that might need to be included or the information could be listed as examples in a survey question that asked, "How often do you use your laptop for other purposes (WebQuests, mathematics tutorials, mathematics software, etc.) in your mathematics classroom?" Discussions with the professional development providers and the project designers could reveal what the desired usage of laptops in the mathematics classroom was. If these categories of desired usage were included in the survey questions, MLTI could get feedback as to the implementation of the techniques taught in the professional development as well as the impact on mathematics achievement of using those techniques. With these better measures, one could possibly find out whether near transfer of learning (Haskell, 2001) occurred for the teachers as they transferred learning from their professional development to their classroom teaching. Likewise, one could possibly determine if near transfer of learning occurred for the students as they transferred learning from their technology-enhanced activities in the mathematics classroom to the achievement test items.

Refinement of the Measure of Calculator Usage

The observations of the pre-service teachers in eighth grade mathematics classrooms about the availability of calculators in the classroom suggests that a survey question related to calculator access could give insight into mathematics education in the state of Maine. Such a survey question might ask, "Do you have access to a calculator in your classroom, and if so, what type?" The choices could be: A. There are enough graphing calculators in my classroom for each student to be able to use one; B. There are enough non-graphing calculators in my classroom for each student to be able to use one; C. There are no (or only a few) calculators in my classroom, but I have my own graphing calculator; D. There are no (or only a few) calculators in my classroom, but I have my own non-graphing calculator, and e. There are no calculators in my classroom and I do not have one of my own.

Recommendation to Facilitate Future Studies of Teaching and Learning with Technology

Indicators of Problem-based and Project-based Teaching and Learning

A survey question on the MEA was, "Which statement best describes your mathematics classes?" The choices were: A. Most of the time the teacher talks about mathematics and I work by myself to do assignments from the book, B. Most of the time the teacher talks about mathematics and I work by myself to investigate and solve problems, C. Most of the time the teacher talks about mathematics and we work in groups to investigate and solve problems, and D. a balanced combination of A, B, and C. In a classroom where problem-based and project-based learning is being implemented, one would expect to see more students choosing C or D, whereas students in a traditional classroom would probably experience more of the situations described in A and B. At the classroom level, the answers to this question could be used as an indicator of project-based and/or problem-based learning. At the school-wide level in the current study, this data was not useful. It was possible to calculate a state average and see that some group work to investigate and solve problems is already happening in the state of Maine as reported by eighth grade students. As shown in Figure 12, 15.4% of the eighth graders selected choice C. Most of the time the teacher talks about mathematics and we work in groups to investigate and solve problems, while 46.9% selected choice D. a balanced combination of A, B, and C.

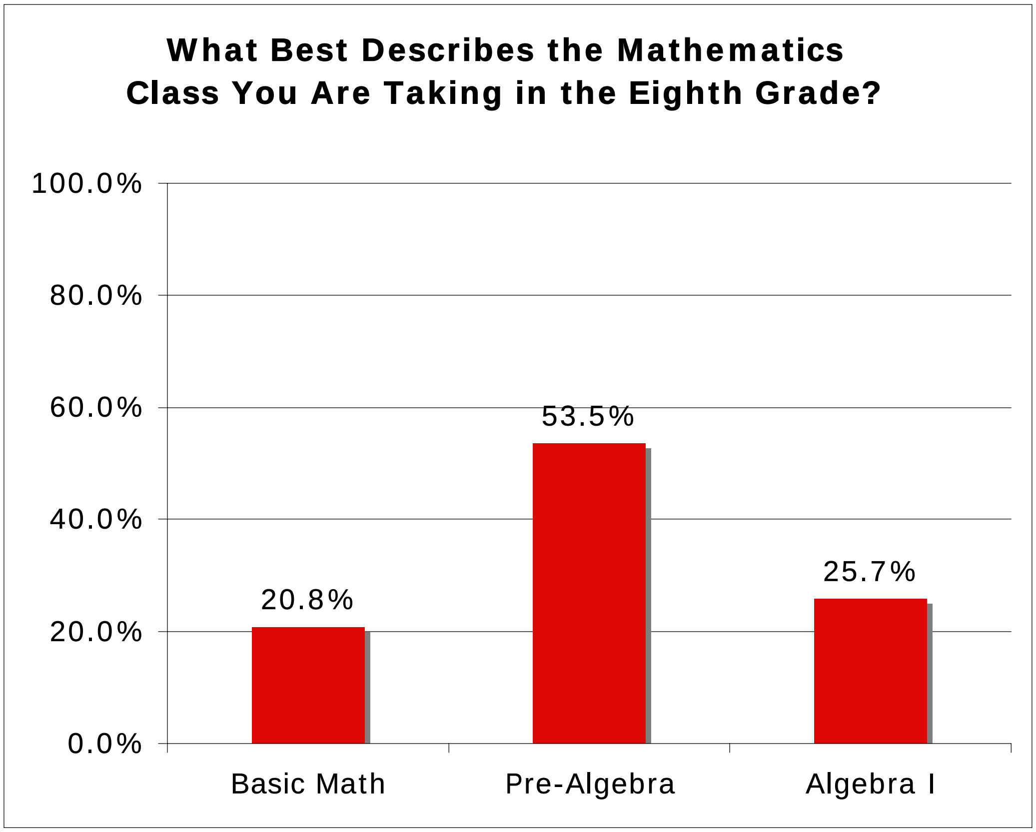

Figure 12. Distribution of eighth grade student responses in the state of Maine (n = 16,458) describing their mathematics instruction.

An MEA survey item that could possibly serve as an indicator of project-based and problem-based assessment being used in the classroom (which would be expected to be an indicator of project-based and problem-based teaching and learning) asked, "How often do you do assignments or take tests in mathematics that are scored with a rubric (where you can earn partial credit)?" The choices were: A. most of the time, B. sometimes, and C. never. Again, this item when reported at the school level and when not disaggregated by gender was not helpful in the current study. However, the data were able to be used to show that at the state level, in spring 2004, rubrics were already being utilized. As shown in Figure 13, 46.7% of the students reported that rubrics were used for scoring in their mathematics classes while 22% reported rubric usage most of the time. This could serve as a baseline for future studies to see if problem-based and project-based assessment occurring in the classroom changes over time.

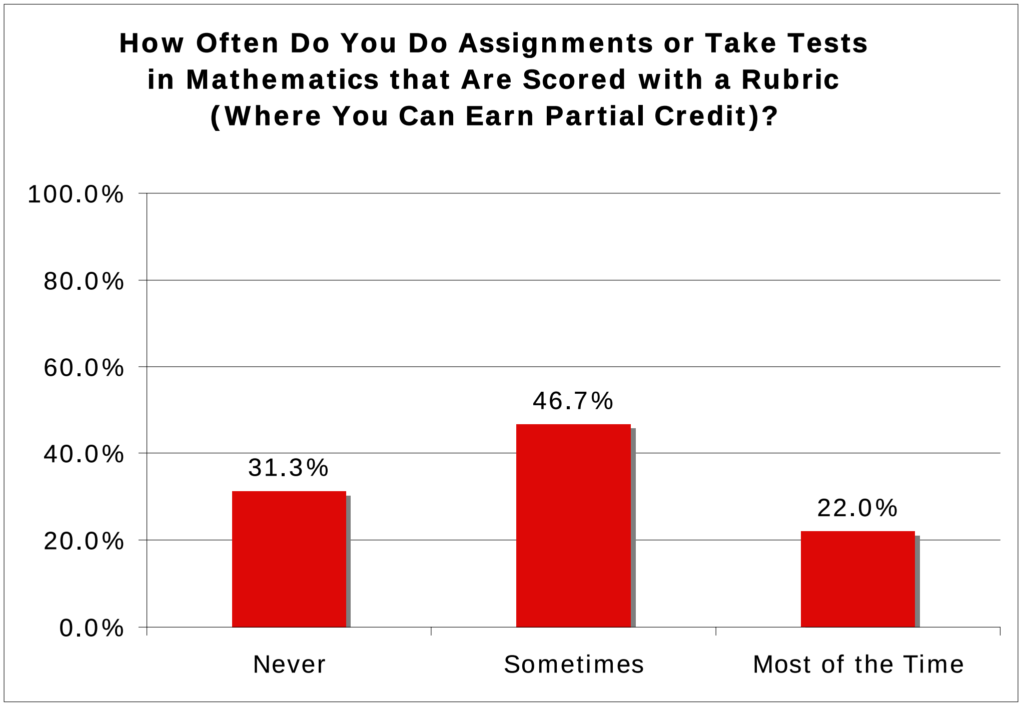

Figure 13. Distribution of eighth grade student responses in the state of Maine (n = 16,458) describing the use of rubrics for scoring in their mathematics class.

A third MEA survey question that could serve as an indicator of project-based and/or problem-based learning and assessment in the mathematics class was, "My grades in mathematics depend mostly on" and the choices were: A. tests and quizzes, B. tests, quizzes, and homework, C. journals and portfolios, and D. a combination of B and C. Choices A and B are more reflective of a traditional mathematics curriculum while the use of journals and portfolios could be an indicator of project-based and/or problem-based learning being carried out in the mathematics classroom. In the spring 2004 data, when the results were calculated out to the state level, this survey question revealed (see Figure 14) that only 2.7% of the eighth graders felt their grades in mathematics depended mostly on journals and portfolios and only 14.8% reported that their grades depended mostly on a combination of tests, quizzes, homework, journals, and portfolios. The remaining 82.4% reported that their grades in mathematics depended mostly on the traditional grading methods of tests, quizzes, and homework.

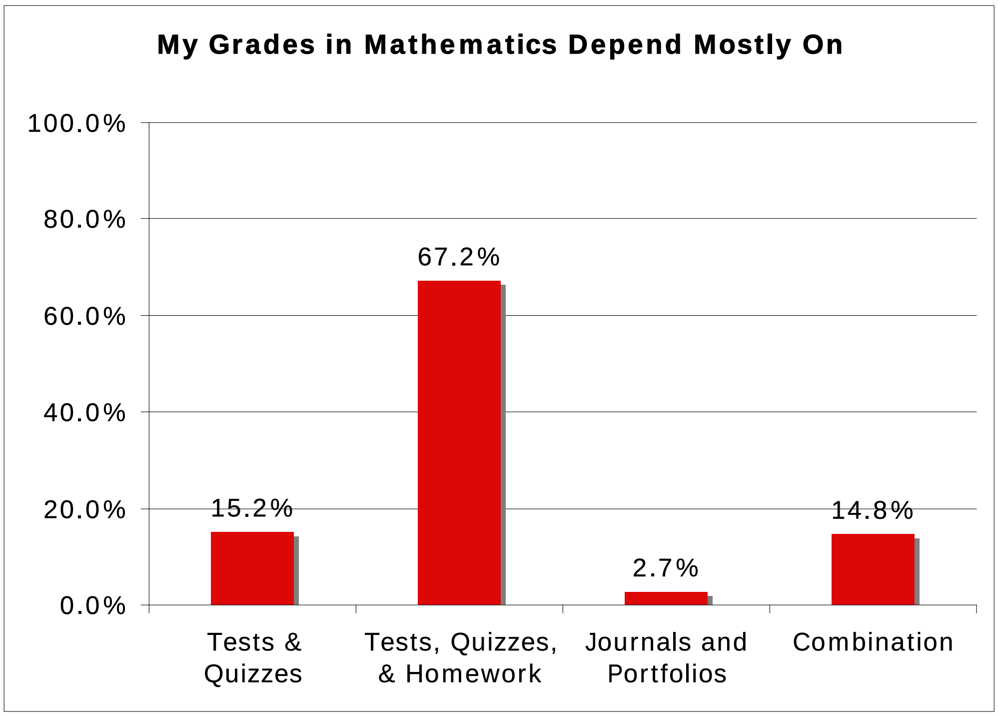

Figure 14. Distribution of eighth grade student responses in the state of Maine (n = 16,458) describing the grading methods in their mathematics class.

Recommendations for Future Studies

As described in Chapter One, this study was intended to address a multi-faceted question of technology's potential for strengthening the learning of mathematics for both girls and boys. The MEA School Profile was rich in its data in that it offered the results to student survey questions about the implementation of curriculum in the classroom in addition to traditional achievement scores. At the same time, the data were constraining in their disaggregation by groups other than what was needed and (in some cases) perhaps weak measurement of what was intended. Additionally, it is known from the MEA Technical Manual (Measured Progress, 2004) that data were collected that could shed light on these questions but were not reported in the School Profile. The following section offers several proposed studies that could better address the heart of the question: Can one-to-one technology help produce near transfer of learning of mathematics for girls and for boys?

Design for a Proposed Study of Teaching, Learning, and Technology

Assuming one had access to the MEA source data and not just the School Profile, an effective study would be to use the classroom as a unit of study instead of the school and use a measure of “level” of laptop usage instead of “variety” of laptop usage. If the MEA survey item on laptop usage was to be revised to be three or four questions about the frequency of laptop usage in the mathematics classroom in various categories, analysis could be done on each laptop usage or a linear combination of all the categories to create one overall indicator of level of laptop usage. As described previously, there are survey questions on the MEA that could be indicators of level of implementation of problem-based and project-based teaching. The mathematics achievement scores could be an indicator of Haskell's near transfer of learning, where a student takes a concept learned in a mathematics class and applies it to a question covering the same concept on a multiple-choice or short answer achievement test question.

Regression analysis could be run with level of project-based / problem-based implementation (teaching), math achievement (learning), and level of laptop usage and/or calculator usage (technology) at the classroom level. The results could determine if there is a near-transfer-of-learning of mathematics concepts taught in a project-based / problem-based curriculum using one-to-one technology.

Proposed Gender Studies Using MLTI and MEA Data.

If a researcher were able to access the MEA data disaggregated by gender, one could run regression analyses to determine if implementation of problem-based and project-based learning was a predictor of girls' and boys' mathematics achievement. One could run regression analyses to determine if level of calculator use and/or level of laptop use were good predictors of girls' and boys' mathematics achievement. Additionally, one could compare the results in either study to determine if any one of the variables was a stronger predictor for girls compared to for boys.

Calculator usage had the second largest association after socio-economic status in the Pearson Correlations for both boys (r = .22) and girls (r = .22). This was statistically significant at the $p < .01$ level. Although the exact cause for the association is unknown, the fact that the association is equal for boys and for girls in the state of Maine is important information in light of Burrill's (2002) directive that more studies are needed to discern how the characteristics and achievement of calculator-using students vary with regard to gender. Further study using the MEA raw data on achievement, demographics, and self-report level of calculator usage in classroom instruction can shed light on gender differences or similarities regarding the effects of calculator usage on mathematics achievement.

In the evaluation of the top 25% (n = 45) and the lower 25% of the schools after they were rank-ordered based on an average mathematics score for the entire school, regardless of gender. There was no statistically significant ($p < .05$) difference between school-wide girls' mathematics achievement score and school-wide boys' mathematics achievement score, in the highest performing schools. Relative to mathematics achievement, girls and boys perform equally as well on the mathematics achievement test. In the lower 25% of the schools, there was a statistically significant difference ($p = .01$) between the school-wide average of girls' mathematics achievement score and the boys' score with girls performing better than the boys on the achievement test. The effect of gender for this group was .447 which is educationally meaningful according to established guidelines (Bialo & Sivin-Kachala, 1996).

This finding reaffirms the state of Maine's concern when it set up the Task Force on Gender Equity in Education out of concerns about the poor academic performance by boys. Further study is needed to not only discern what is helping the boys at the schools in the top 25% to score a school average of 12.71 points higher than the boys' average in the lower 25% schools. Additionally, studies should be carried out to discern what is hampering successful math achievement for all students but especially the boys who score on average 1.5 points below the girls in the lower 25% of the schools. For the top performing eighth grade schools in the state of Maine it reaffirms Maggie Ford's vision that “in a gender-equitable and rigorous school system, gender gaps would be insignificant and all students would excel” (American Association of University Women (AAUW), 1999, p. iv).

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